# 3.1 GEOLOGY

**SYNOPSIS**

**Summary of Existing Conditions:**

This section presents information available regarding the physiography, bedrock geology, surficial geology, aggregate resources, and paleontological resources within the areas affected by the three proposed project components: mine site, transportation facilities, and pipeline. The EIS Analysis Area encompasses seven physiographic sub-provinces spread across Southwest and Southcentral Alaska and the Aleutian Island Chain. Regional descriptions of these resources are presented, followed by local descriptions, and enhanced with information gathered from project geotechnical studies.

**Expected Effects:**

Alternative 1: No Action – This alternative is representative of existing conditions. No project-related impacts to geological and paleontological resources would occur under this alternative.

Alternative 2: Donlin Gold's Proposed Action – *Mineral Resources:* Under the Proposed Action, impacts to mineral, rock aggregate, and gravel resources at the mine site, transportation facilities, and pipeline components would range from low intensity (e.g., minor grading) to high intensity (e.g., blasting, major landform changes, widespread aggregate utilization). Project activities would result in the alteration of the following:

- *Mineralized bedrock and waste rock*: roughly 3.5 billion tons across 7,000 acres for ore extraction at the mine site, with topographic changes up to about 600 feet;
- *Rock aggregate*: extraction of 5.6 million cy across 900 acres from material sites, and cuts along roughly 90 miles of roads and pipeline ROW; and
- *Gravel resources and surficial deposits*: 40 million tons of overburden moved and reused for reclamation across about 9,000 acres at the mine site; 4.6 million cy of gravel resources extracted from material sites; alteration of surficial deposits along 340 miles of roads and pipeline ROW; and 2,800 acres of material sites and pipeline infrastructure.

Most effects would be permanent (e.g., landscape changes and reduction in mineral/aggregate resources) and local as they would be limited to areas within the various facility footprints. Most rock and gravel aggregate resources impacted are considered common in context, although the ore-containing bedrock at the mine is a unique economic resource. Net effects to mineral and aggregate resources under Alternative 2 would range from minor to moderate.

*Paleontological Resources:* Impacts would range from low intensity (from minor grading) to high intensity (e.g., blasting at the mine and material sites), depending on the actual presence of fossils. The total volumes and acreages of potential fossil-bearing rock that could be affected by project activities would be similar to those summarized for bedrock and gravel resources. Fossils across the EIS Analysis Area range from common in context (e.g., abundant invertebrates present) to potentially important (e.g., dinosaur tracks, Pleistocene mammals). Overall direct and indirect effects on paleontological resources under Alternative 2 would be minor to moderate.

Alternative 3A (LNG-Powered Haul Trucks): The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about 20 fewer acres of ground disturbance and landform alterations at the Bethel and Dutch harbor fueling facilities. Net overall effects would range from minor to moderate.

Alternative 3B (Diesel Pipeline): The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about 20 fewer acres of ground disturbance and landform alterations at the mine and transportation facilities, and about 1,400 acres more ground disturbance and extraction of surficial geologic resources along the extended pipeline ROW. Net overall effects would range from minor to moderate.

Alternative 4 (Birch Tree Crossing [BTC] Port): The BTC Road would utilize about 11 million cy more rock and gravel aggregate, and cause landform changes across about 900 more acres, than the Angyaruaq (Jungjuk) Road under Alternative 2. There would be a net increase in the probability of potential effects on paleontological resources under Alternative 4 due to the higher number of bedrock rock material sites along the BTC Road. However, the reduction on upper river barge travel under Alternative 4 would reduce potential effects on vertebrate fossils along the river corridor. Overall, effects to geological and paleontological resources under Alternative 4 would range from minor to moderate.

Alternative 5A (Dry Stack Tailings): The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. The final elevation of the dry stack would be 50 to 150 feet higher than the existing ridge south of the TSF. There would be about a 12 percent increase in the amount of bedrock excavation and aggregate needed for the main and upper dry stack tailings dams than under Alternative 2. Net overall effects would range from minor to moderate.

Alternative 6A (Dalzell Gorge Route): The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about 3 fewer material sites covering about 130 acres than Alternative 2. Net overall effects would range from minor to moderate.

## 3.1.1 REGULATORY CONTEXT

### 3.1.1.1 MATERIALS SITES

"Materials" are defined as any substance from the ground that may be utilized as part of mine construction, but are not economically mineralized or part of the mineral claim itself. Examples would include sand, gravel, riprap, soil, rock, and any other similar substance. These materials might be used for construction of roads, pads for performing work, shoreline protection, etc. Use and placement of these resources is governed by a variety of state and federal laws and regulations.

A portion of the pipeline route would run through Kenai Peninsula borough (KPB). Use of the gravel would be covered under KPB Code of Ordinances, Chapter 21.29, which regulates materials extraction, processing, and excavation below the water table.

Alaska Statute [AS] 38.05.110-120 and 11 AAC 71 would govern borrow materials not located within the boundary of the millsite lease or a road ROW. Each site would require a Development Plan that addresses the handling of timber and slash, a bond, and a Reclamation Plan. An Alaska Pollutant Discharge Elimination System (APDES) Multi-Sector General Permit may be required, as well as Excavation Dewatering General Permit. These would both be administered by the Alaska Department of Environmental Conservation (ADEC). These permits control both the discharge of stormwater, and dewatering effluent.

Additional permits would be required from Alaska Department of Natural Resources (ADNR), including a Temporary Water Use Permit, and a material sale application if the pit is on state land.

The Bureau of Land Management (BLM) sells the materials from their land at not less than fair market value, as determined by appraisal. Regulations governing contracts and permits for mineral materials are contained in Title 43, Code of Federal Regulations, Subparts 3601, 3602, 3603, and 3604. Mineral resources used for the project would be sold to the proponent as a minerals material sale. BLM typically considers addressing the need for mineral materials after other options on non-BLM-managed lands are fully explored.

### 3.1.1.2 PALEONTOLOGY

Paleontology is a multi-disciplinary science that combines elements of geology, biology, geochemistry, and physics in an effort to understand past life on earth. Paleontological resources, more commonly known as fossils, are the remains, traces, or imprints of ancient animals and plants preserved in sediment and rock. Paleontological resources include mineralized, partially mineralized, and non-mineralized bones, skeletal material and invertebrate remains, and also skin imprints, footprints and tracks, as well as plant macro- and microfossils that have the potential of yielding important information about the history of life on earth.

These are non-renewable resources of scientific value that are protected by Federal laws including:

- The Paleontological Resources Preservation Act of 2009;
- Antiquities Act of 1906; Archaeological Resources Protection Act of 1979;
- Federal Land Policy and Management Act of 1976 (as amended 1998).

Specific provisions for federal land-managing agencies reinforce policies regarding the collection and curation of paleontological resources. The BLM assesses potential impacts to paleontological resources under the Federal Land Policy and Management Act (FLPMA) and the National Environmental Policy Act (NEPA), and provides guidance for predicting, assessing, and mitigating paleontological resources (BLM 1998). This is done by utilizing Instruction Memorandum No. 2009-011, the Potential Fossil Yield Classification (PFYC) system, and the Handbook H-8270-1 (General Procedural Guidance for Paleontological Resource Management) Chapter III (Assessment & Mitigation).

The State of Alaska protects fossils under the Alaska Historic Preservation Act (AS 41.35), which explicitly includes paleontological materials in its definition of “historic, prehistoric, and archaeological resources,” and requires the ADNR to locate, identify, and preserve information on paleontological resources. In accordance with the federal and state regulations, exact locations of paleontological resources are restricted and exempt from federal and state Freedom of Information laws.

## 3.1.2 AFFECTED ENVIRONMENT

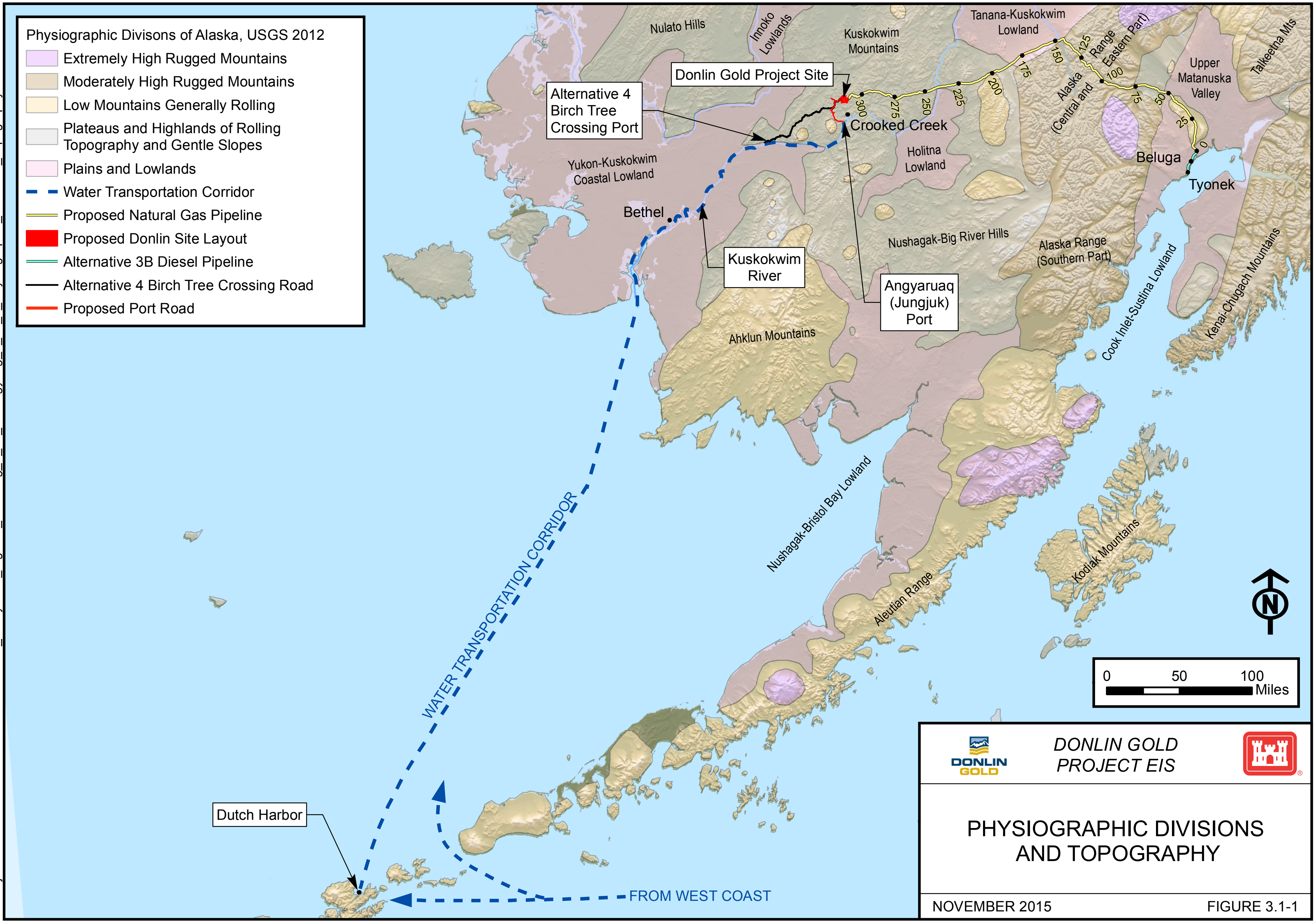
This section presents information available regarding the physiography, bedrock geology, surficial geology, aggregate resources, and paleontological resources within the areas affected by the three proposed project components: mine site (Section 3.1.2.1), transportation facilities (Section 3.1.2.2), and pipeline (Section 3.1.2.3). The EIS Analysis Area encompasses seven physiographic sub-provinces spread across Southwest and Southcentral Alaska and the Aleutian Island Chain. Regional descriptions of the geological resources are presented below, based on state and federal government research, and related thematic studies as presented in scientific journals. These are followed by local descriptions, enhanced with information gathered from project geotechnical studies, where available.

### 3.1.2.1 MINE SITE

Geologic features associated with the mine site area are discussed in the sections below. The vegetation found in the area of the mine site is discussed in Section 3.10, Vegetation, including a discussion of ecoregions in Section 3.10.2.1. Permafrost is discussed in Section 3.2, Soils. Surface water and river systems are discussed in Section 3.5, Surface Water Hydrology.

#### 3.1.2.1.1 PHYSIOGRAPHY

The area of and surrounding the proposed mine site includes rounded mountains, occasional oxbow and thaw lakes, and creek drainages leading to the Kuskokwim River. Specifically, the proposed mine site lies within the Kuskokwim Mountains physiographic sub-province of the larger Uplands and Lowlands Western Alaska province of the Intermontane Plateaus physiographic division (Figure 3.1-1) (Wahrhaftig 1965, 1994). The Kuskokwim Mountains, which trend northeast, consist of rounded mountaintops with elevations up to about 2,000 feet. Lookout Mountain, located approximately 1 mile northeast of the proposed mine site facilities, reaches an elevation of 2,146 feet, and Anaconda Ridge, located within the proposed mine site, has an elevation of 2,112 feet. The primary drainages of the Kuskokwim Mountains physiographic province are the Yukon and Kuskokwim rivers that discharge into Norton Sound and Bristol Bay, respectively. Glacial landforms have been recognized in the higher elevations of the range (Meyer 1985; Kline and Bundtzen 1986). Oxbow and thaw lakes occasionally occur in the valleys of this province (Wahrhaftig 1965).

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The proposed mine site lies within a northeast-trending ridge predominantly drained by west-flowing tributaries to Crooked Creek, which discharges into the Kuskokwim River approximately 10 miles to the south. The mine site physical footprint encompasses an area of approximately 25 square miles. The proposed ore processing footprint is bounded to the northeast by Quartz Gulch, to the northwest by Donlin Creek, to the west by Crooked Creek, to the south by Crevice Creek, and to the east by Anaconda Ridge (Figure 2.3-1). The top of the proposed excavated pit lies at an elevation of approximately 1,400 feet, and is bounded to the south by American Creek and to the north by a ridge between Lewis and Queen gulches. American Creek and Queen Gulch flow westward and discharge into Crooked Creek. The proposed waste rock facility lies to the southeast of the proposed pit within the upper reaches of American Creek. The proposed Tailings Storage facility (TSF) lies south of the waste rock facility within the Anaconda Creek drainage.

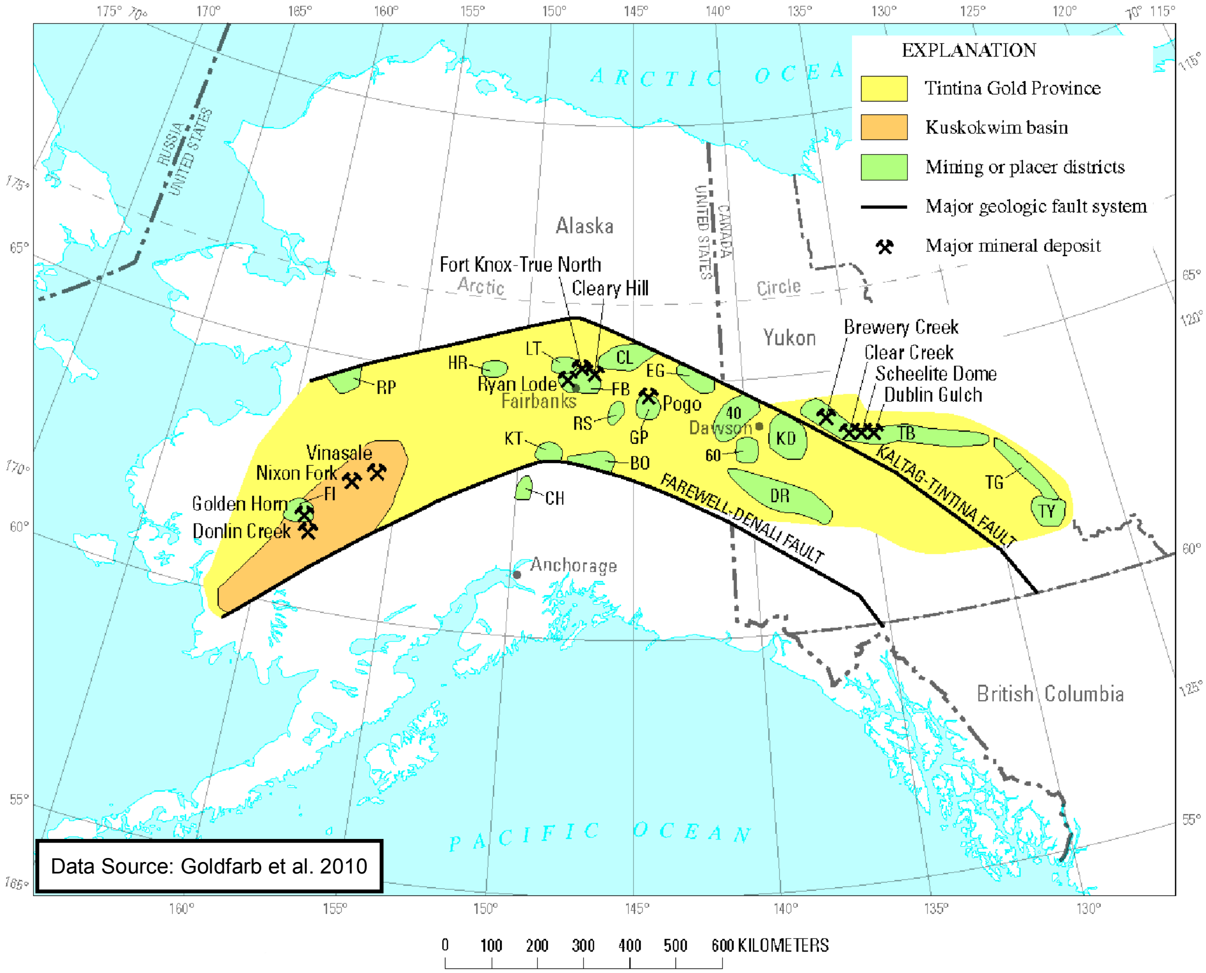
### 3.1.2.1.2 BEDROCK GEOLOGY

Geology of the proposed project can be broken into two areas of study: the bedrock geology, and the surficial geology. The bedrock is defined as the solid (consolidated) rock of the earth's surface. As this rock weathered over time it breaks apart (becomes unconsolidated) and forms soils and loose rock. These materials are discussed as surficial geology (Section 3.1.2.1.3).

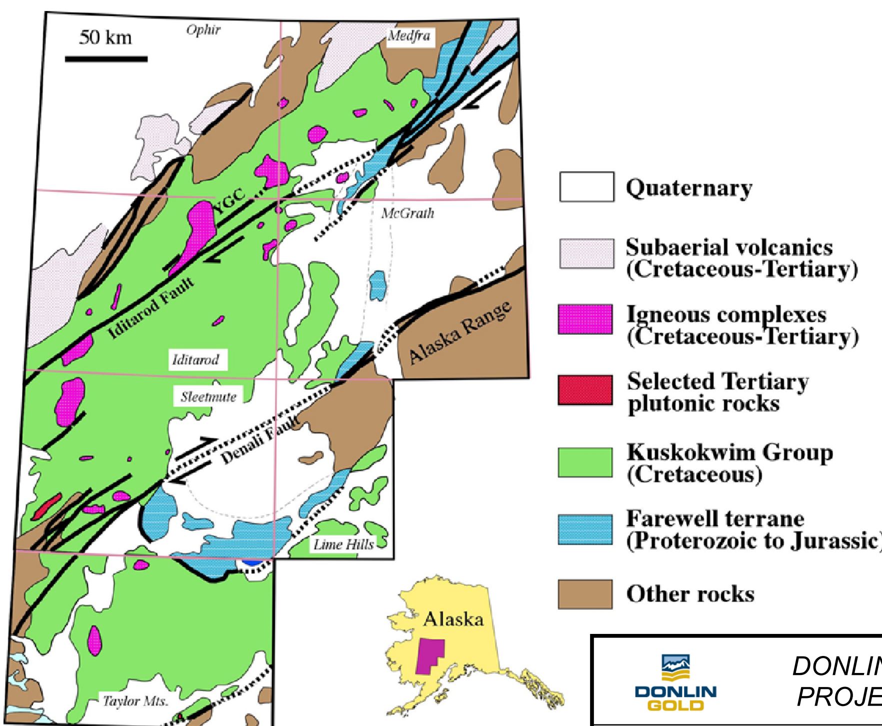
#### Regional Bedrock Geology

The greater geologic region that includes the EIS Analysis Area lies in the center of the Kuskokwim Mineral Belt at the southwestern end of the larger Tintina Gold province, a broad arc-shaped region of mineral deposits that is bounded on the north and south by major fault systems and extends east into Yukon Territory, Canada (Bundtzen and Miller 1997; Goldfarb et al. 2010) (Figure 3.1-2). The Kuskokwim Mineral Belt hosts numerous placer (unconsolidated) and bedrock precious-metal-bearing deposits. The central portion of the Tintina Gold province hosts the Fort Knox Gold Mine near Fairbanks and the Pogo Gold Mine near Delta Junction. The eastern part hosts the largest gold mine ever constructed in the Yukon, the Brewery Creek Mine (Yukon Energy Mines and Resources 2013), and the Eagle Gold Project, south of Dawson City, which is currently in the development stage of a multi-million-ounce gold resource (Wardrop 2012).

The regional bedrock geology of the area is a complex mixture of sedimentary, igneous, and metamorphic rocks ranging in age from Cenozoic to Proterozoic (Decker et al. 1994; Bundtzen and Miller 1997; Wilson et al. 1998). The bedrock of the region can be grouped into "terranes", that is, related groups of rocks separated by faults (Plafker and Berg 1994; Silberling et al. 1994; Miller et al. 2008; Goldfarb et al. 2010). In this region these faults are the Denali-Farewell and Iditarod-Nixon Fork faults. These are strike slip faults, and trend northeast through the Kuskokwim Basin and mountains (Plafker et al. 1994; Decker et al. 1994; Miller et al. 2008).




Data Source: Goldfarb et al. 2010




Data Source: Miller et al. 2008

DONLIN GOLD PROJECT EIS

# REGIONAL GEOLOGY AND MINE SETTING

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FIGURE 3.1-2

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## Mine Bedrock Geology

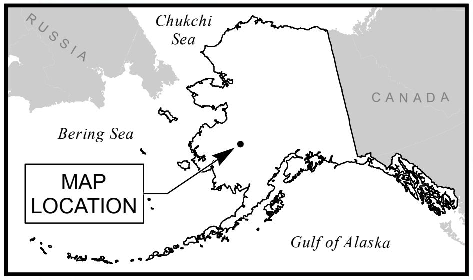
Bedrock geology at the proposed mine site consists of sedimentary rocks of the Kuskokwim Group, with younger, late Cretaceous to early Tertiary, intrusions of igneous (solidified from lava or magma) rocks of the Kuskokwim Mountains Group (Decker et al. 1994; Bundtzen and Miller 1997; Szumigala et al. 2000; Miller et al. 2008; Goldfarb et al. 2010). The Kuskokwim Group rocks consist of a deep marine sequence of greenish-gray colored, fine- to coarse-grained, thinly cross-bedded graywacke sandstone, with interbeds of dark gray siltstone and shale that have experienced low grade regional metamorphism and deformation (Cady et al. 1955; Dusel-Bacon et al. 1996; Szumigala et al. 2000).

The bedrock at the proposed mine site has a complex history of folding, faulting, and intrusion. An east-west trending fold deforms the Kuskokwim Group rocks. A local sub-parallel fault of the Iditarod-Nixon Fork fault, the Donlin Creek Fault, is located 1 mile northwest of the proposed mine site. After folding and faulting, it appears that molten igneous rocks intruded along the north-northeast and west-northwest trending structural weaknesses. This created numerous dikes and sills (Figure 3.1-3). This was followed by cross-cutting high-angle faulting along northeast and northwest trends. Finally extensional fractures cross-cut all previous structures, and are concentrated within the igneous and coarse-grained sedimentary rocks (Goldfarb et al. 2004). It is these structures that are gold bearing.

The proposed mine targets bedrock associated with the dike and sill complex. The rock consists of plutonic granite porphyry[1] to volcanic dacite/rhyodacite. The rock is categorized as hydrothermal mercury-antimony-gold intrusion (Goldfarb et al. 2004, 2010; Bundtzen and Miller 1997; Gray et al. 1997a; Robert et al. 2007; Szumigala et al. 2000; Flanigan et al. 2000). Similar mineralization has been well documented throughout Southwest Alaska (Frost 1990; Frost and Box 1991; Gray et al. 1990; Gray and Sanzolone 1996; Zamzow 2012).

The Donlin mineral deposit is characterized as both vein-hosted and disseminated ore that developed within a shallow, low-temperature hydrothermal system. Gold occurs primarily in the igneous rhyodacite rock and minor mafic intrusive rocks, as well as in sulfide and quartz-carbonate-sulfide vein networks in igneous and sedimentary rocks (Robert et al. 2007; Flanigan et al. 2000; Bundtzen and Miller 1997; Goldfarb et al. 2004, 2010). The ore mineralogy is characterized by sulfide assemblages of pyrite, arsenopyrite, and stibnite (Szumigala et al. 2000; SRK Consulting (US), Inc. [SRK] 2006a; AMEC Americas Limited [AMEC] 2009). Pyrite is attributed to the earliest sulfide mineralization phase and arsenopyrite is the dominant gold-bearing mineral (Szumigala et al. 2000). The primary alteration phase is a sericite assemblage found predominantly in the intrusive rocks, and characterized by sericite, illite, and kaolinite. The geochemistry of the ore and its relationship to water quality is presented in Section 3.7, Water Quality.

[1] Porphyry is a rock texture describing the presence of large crystals within a groundmass of smaller aphanitic crystals, that is, small-size minerals that cannot be seen with the unaided eye.

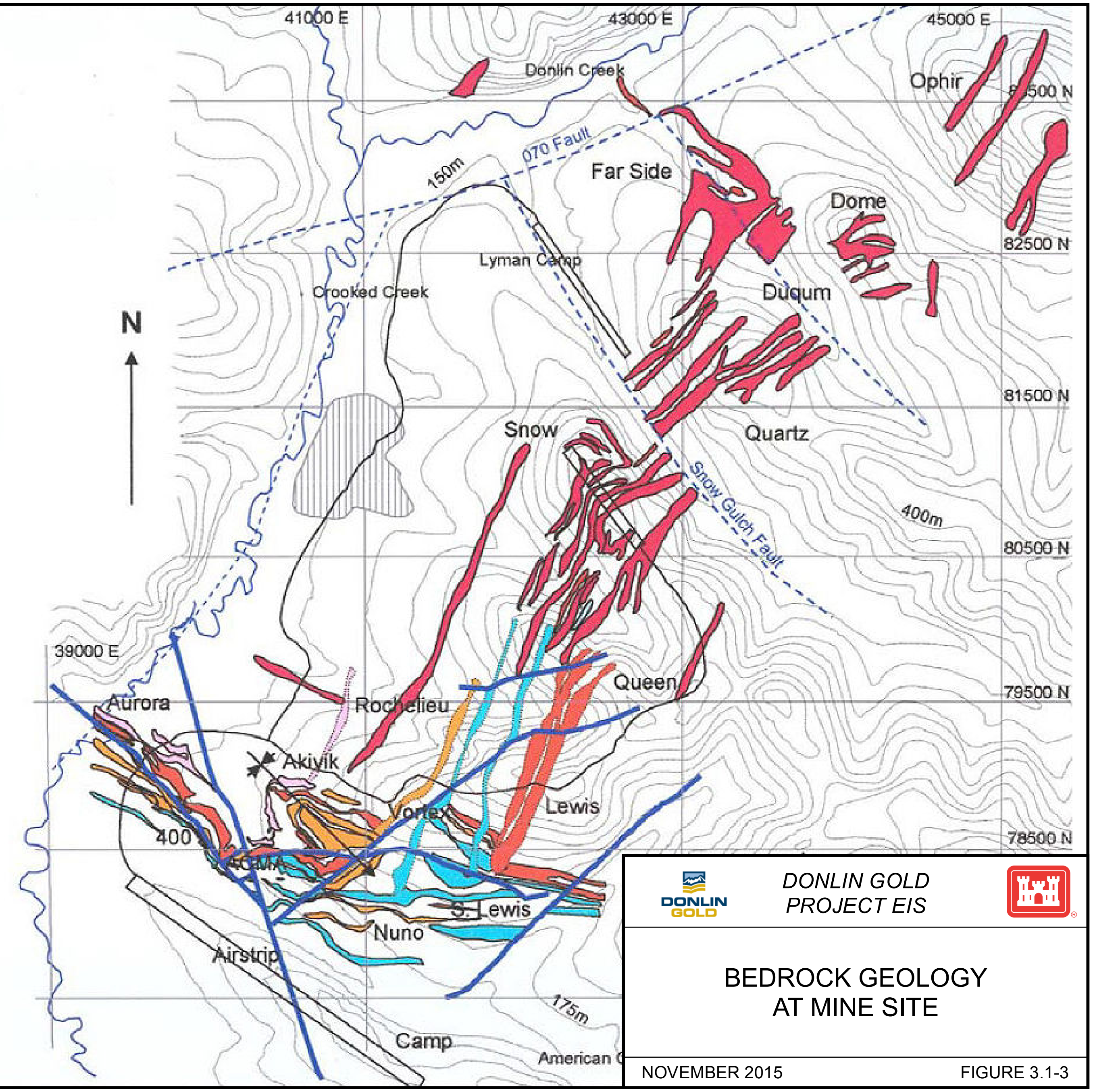



## Legend

**Intrusive Rocks Differentiated by Donlin Gold:**

- Aphanite Porphyry (RDA)
- Crowded Porphyry (RDX)
- Lath-Rich Porphyry (RDXL)
- Blue Porphyry (RDXB)
- Undifferentiated Intrusive Rocks
- Kuskokwim Group Sedimentary Rocks
- Faults
- **Ophir** Gold Prospect Mine
- Placer Mining Area
- 25m Topo Contour
- Creeks
- Roads
- Airstrips

1000 Meters




Data Sources: Hanson et al. 2009

DONLIN GOLD

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BEDROCK GEOLOGY AT MINE SITE

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FIGURE 3.1-3

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### 3.1.2.1.3 SURFICIAL GEOLOGY

Surficial geology includes the unconsolidated materials above the bedrock. These materials may consist of soil (sand, gravel, peat, etc.) or broken rock. These unconsolidated materials originate through the chemical, physical, and biological weathering of the underlying rock. These materials are important to the project since they may be excavated and used for construction. Soil types and taxonomy classifications are presented in Section 3.2, Soils.

Surficial deposits in the proposed mine site area include colluvium[2] on hill slopes, and coarse- and fine-grained alluvium[3] associated with upland valleys and stream courses, such as the Crooked Creek drainage and its tributary streams (Karlstrom et al. 1964). The region has been dominated by the deposition of fluvial[4] material since the last glacial advances in the Alaska Range (Péwé 1975; Reger et al. 2003a). Small accumulations of loess[5] have also been mapped in the Kuskokwim River Basin (Péwé 1975).

Geotechnical studies conducted in 2004 through 2011 for the proposed Donlin Gold Project inspected surficial geology baseline conditions in and around the proposed mine site. These studies included geophysical surveys, excavation of soil test pits, drilling of exploratory borings, installation of groundwater wells, hydrogeological testing, landslide surface investigations, open pit slope stability analysis, fault studies, permafrost investigations, and geochemical testing for ore processing. The geophysical surveys consisted of shallow surface seismic refraction and downhole shear wave testing. Approximately 4,350 feet of seismic refraction surveying was conducted across nine separate seismic traverses at the mine site facility. The downhole shear wave tests were conducted in three test borings, one at the proposed location of the Upper Contact Water Dam and two at the proposed plant site. The purpose of the geophysical surveys was to evaluate the thickness of unconsolidated material above bedrock and to assess the competency (seismic stability) of the bedrock (BGC 2009a). More than 100 test pits were excavated and over 200 exploratory borings were drilled at select locations in the proposed mine site area for analysis of soil and rock physical characteristics. Soil and permafrost are described in Section 3.2, Soils, and other geotechnical conditions in Section 3.3, Geohazards and Seismic Conditions. Groundwater wells were installed in more than 50 of the exploratory borings. Hydrogeological conditions of the mine site are presented in Section 3.6, Groundwater Hydrology.

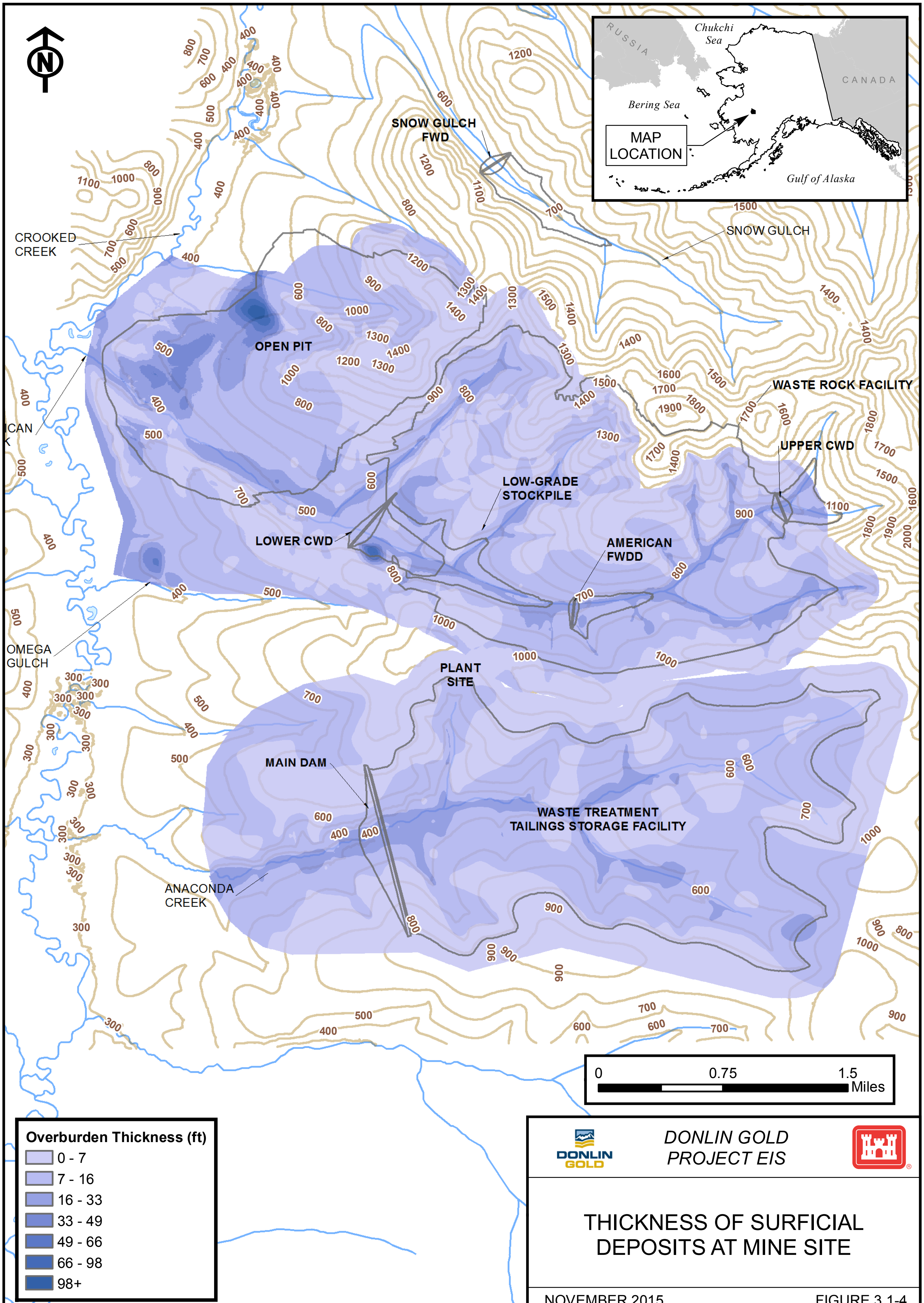
The thickness of surficial deposits identified during the geotechnical studies is shown on Figure 3.1-4. These include colluvium, alluvium, loess, and glaciofluvial deposits as described below (BGC 2005, 2007a, 2009a, 2010, 2011d):

[2] Colluvium is a general term applied to loose material displaced by gravity or freeze-thaw mechanisms (solifluction). Colluvium found at the foot of steep slopes includes talus and cliff debris.

[3] Alluvium is detritus material picked up and deposited by flowing water. Alluvium is generally observed in stream beds, floodplains, and lake beds.

[4] Fluvial refers to rivers and streams and the material produced from their action. Glaciofluvial materials have been deposited by streams flowing from glaciers.

[5] Loess is fine-grained (silt) material of glacial origin deposited by wind, also referred to as eolian processes.

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DONLIN GOLD PROJECT EIS

THICKNESS OF SURFICIAL DEPOSITS AT MINE SITE

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FIGURE 3.1-4

- Colluvium was reported to vary from 0.7 feet thick on ridge tops to up to 20 feet thick in the American Creek drainage, and reaches a maximum thickness of 47.5 feet within the proposed mine site in the area south of Lewis Gulch. The colluvium was found to consist of mostly fine-grained material at lower elevations where the thickest portions were measured (BGC 2009a). The colluvium generally includes gray to brown, medium dense, sandy to silty gravel with clay and trace wood fragments; gravel clasts (individual pieces) are blocky, and angular to sub-rounded.
- Alluvium was reported along the length of Crooked Creek in the proposed mine site area and along associated tributary channels. Borehole data indicate thicknesses ranging from 6.5 to 33 feet within the Crooked Creek floodplain. The alluvium ranges from fine sandy silt with trace gravel, to coarse-grained stratified gravels, sands, and silts; which are medium-dense with rounded to subangular gravel clasts.
- Loess was observed throughout the proposed mine site area on ridge tops and stream drainages, as a thin layer ranging from 0.3 to 3.3 feet thick. The loess was found to be light to medium gray-brown, firm, sandy silt with some clay.
- Glaciofluvial deposits, found above the active streambed of Crooked Creek, were recognized as Pleistocene-age terrace gravels. These deposits lie stratigraphically below the loess and colluvium units, and have a measured thickness of up to 49 feet. The terrace gravels include oxidized surfaces, are of dense to very dense consistency, and contain well-graded, gravelly sand with minor silt and clay. Gravel clasts are sub-rounded to rounded and consist of both igneous and sedimentary rock types.

Mine Borrow Sites

Based on the work performed, there would appear to be surficial materials of sufficient quality and quantity to supply the proposed project. The project has identified several locations for “borrow” sites to supply construction materials for the project. Quarried bedrock is blasted, mined, and processed to produce crushed stone, or aggregate, which is used for construction. Large-sized crushed stone, called riprap or armor rock, is typically used for erosion control at stream crossings and along rivers and shorelines. Borrow material gravel is used as sub-base, base, or surfacing on roads or building pad. Bedrock or gravel can be used as aggregate in concrete.

Several borrow material sites have been proposed at the mine site: two on ridges northeast of Snow Gulch and in the upper American Creek drainage south of the Upper Contact Water Dam (Figure 2.3-1); and four along the east side of Crooked Creek, three of which would be co-located with (and predate) overburden stockpiles. The type of material expected at the two ridge sites includes a thin layer of colluvium and loess over weathered and fractured Kuskokwim Group sedimentary rocks. The type of material expected at the lower sites include mostly gravel and sand with some clay associated with alluvial terrace deposits along the ancestral Crooked Creek (Bundtzen 2004).

#### 3.1.2.1.4 PALEONTOLOGICAL RESOURCES

Regional Setting

Cady et al. (1955) used 38 fossil locations to determine the age of the Kuskokwim Group sedimentary rocks as Late Cretaceous. Most fossils in the area consist of marine invertebrate fossils and are more abundant in the younger (upper strata) of the Kuskokwim Group. Fauna include pelecypod and cephalopod mollusks, as well as annelid worms, brachiopods, and barnacles. Fish fossils occur locally, and where present, are abundant. Flora fossils include terrestrial ferns and flowering plants. Most fossil material is fragmental, which suggests transport from place of origin prior to deposition.

Since Cady et al. (1955), Box and Elder (1992) and Elder and Box (1992) identify 15 *Inoceramid* bivalves of Late Cretaceous age in the Kuskokwim Group. Quaternary vertebrate fossils have also been reported in overlying sediments in the area (Reuther et al. 2014).

Mine Site Paleontology

Fossils potentially present at the mine site would likely be contained within Kuskokwim Group sedimentary rocks that have not been altered by hydrothermal processes (i.e., the non-ore-containing bedrock or waste rock). Non-marine strata within the Kuskokwim Group are known to contain abundant plant fossils, which are associated with a high potential for dinosaur tracks and skeletal remains based on geologic similarities with other depositional settings of Cretaceous age, such as the Cantwell Formation of Denali National Park and Preserve (Alaska Dispatch News 2014; Fiorillo et al. 2014; Jacobus and Druckenmiller 2013). While no obvious macrofossils have been found to date in nearby outcrops, exposures of non-marine Cretaceous rocks are limited in the area (Reuther et al. 2014). Drilling activities at the mine site reported the presence of plant fragments, suggesting a non-marine sediment source (Druckenmiller et al. 2013). Gastropods, shell fragments, and fauna of *Inoceramus* species shells were also observed at a drill site within a 3-foot thick mudstone layer bounded by lime-rich turbiditic sandstone.

The fossil potential of the mine region was evaluated using a PFYC system developed by the BLM (Table 3.1-1). This classification provides guidance for predicting, assessing, and mitigating paleontological resources, and is useful in understanding the contextual importance of these resources. The PFYC system serves as a process for determining whether vertebrate fossils, or noteworthy occurrences of other fossils, are known or likely to occur in an area (BLM 1998).

**Table 3.1-1: BLM Potential Fossil Yield Classification (PFYC) System**

| Class | | Descriptions |
|---|---|---|
| 1 | | Very low yield potential and not significant to paleontological research. |
| 2 | | Not likely to contain fossil material, or contains abundant invertebrate specimens valuable to research. |
| 3 | a | Geologic units having a moderate fossil yield potential. |
| | b | Geologic unit with unknown fossil potential. Following BLM guideline, the PFYC system suggests that *Class 3b* units undergo further reconnaissance and research. |

**Table 3.1-1: BLM Potential Fossil Yield Classification (PFYC) System**

| Class | | Descriptions |
|---|---|---|
| 4 | a | Outcrop areas that are more significant and have many exposed bedrock areas with little or no vegetative cover. These may be susceptible to impact from illegal collecting or other surface disturbing actions. *Class 4a* material is protected by a layer of soil or thin deposits of sediment (or other circumstances that limit degradation). |
| | b | High potential but have a lower risk of degradation due to human or environmental impacts. |
| 5 | | Very high and very significant for research and vulnerable to destruction. |

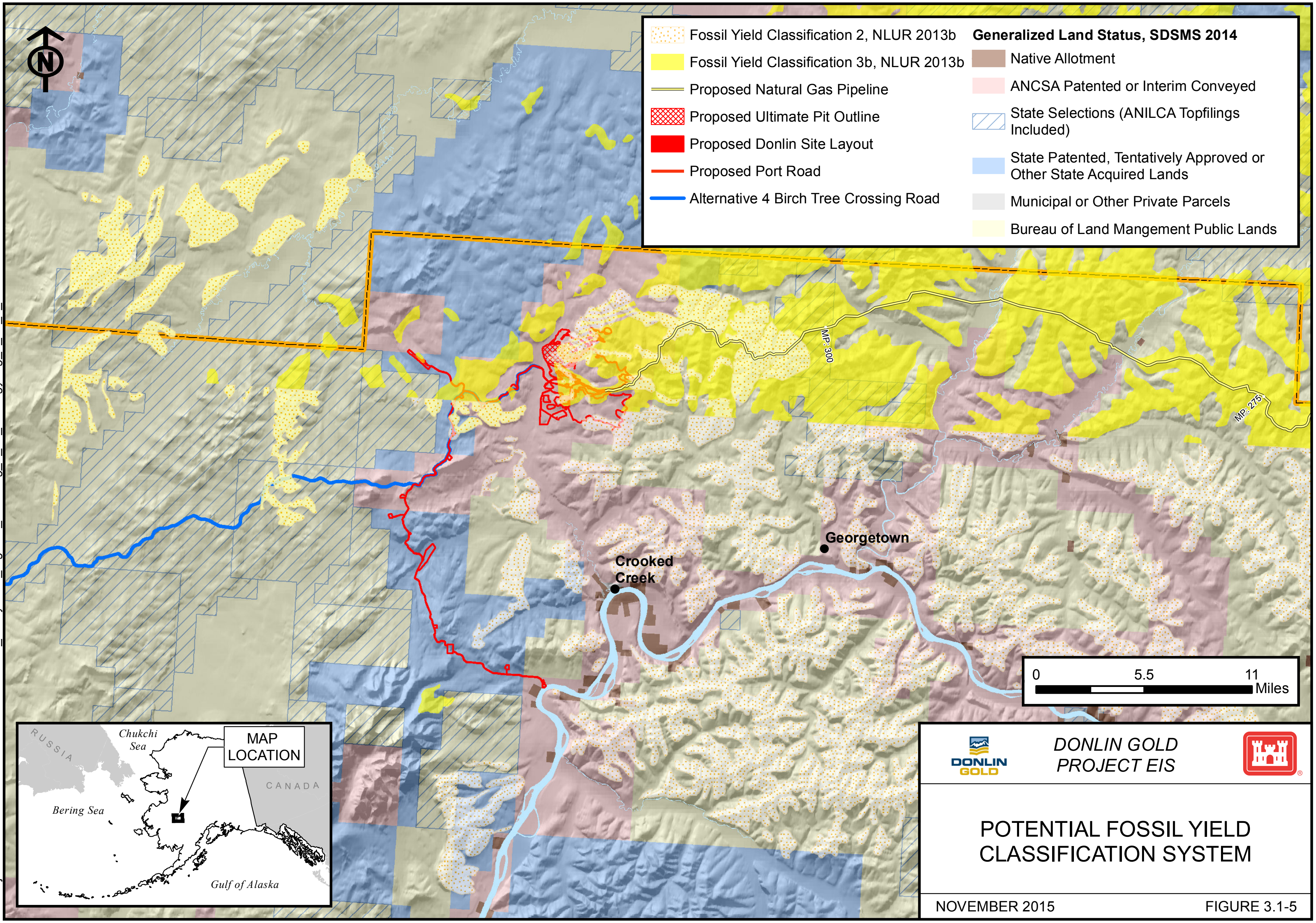
Source: Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013.

Figure 3.1-5 depicts PFYC values for the mine region. Part of the mine site is rated PFYC Class 2 (most of the open pit), indicating low fossil potential or the presence of invertebrate fossils from abundant species; and part of the mine site is rated Class 3b (east and south sides of pit, and areas beneath the WRF and TSF), meaning these rocks have unknown fossil potential and that further reconnaissance and research may be necessary to determine potential impacts, a designation which derives primarily from the potential for dinosaur fossils (Reuther et al. 2014).

### 3.1.2.2 TRANSPORTATION FACILITIES

#### 3.1.2.2.1 PHYSIOGRAPHY

The majority of the proposed transportation facilities (roadway, river port, and new/upgraded dock facilities) lie within the same physiographic region as the proposed mine site, the Kuskokwim Mountains, as well as the adjacent Yukon-Kuskokwim Coastal Lowland sub-province of the larger Bering Shelf province (Figure 3.1-1) (Wahraftig 1965, 1994). The Yukon-Kuskokwim Coastal Lowlands consist of low-lying plains rising from just above sea level to elevations up to 300 feet. The Kuskokwim River is charged by low-gradient, meandering streams within the Yukon-Kuskokwim Coastal Lowlands; it discharges southward into Kuskokwim Bay and Bristol Bay.




DONLIN GOLD PROJECT EIS

POTENTIAL FOSSIL YIELD CLASSIFICATION SYSTEM

NOVEMBER 2015

FIGURE 3.1-5

M:\Projects\26221089 - Donlin Gold EIS\Mxd\Ch_3\Physical_Figures_DEIS\Fig_3_01_Geology\Fig_3_01_5_PotentialFossilYield.mxd

The Angyaruaq (Jungjuk) and Birch Tree Crossing (BTC) road alternatives and their respective port sites are located within the Kuskokwim Mountains, which are drained on the north by the Yukon River and to the south by the Kuskokwim River. The BTC Port alternative crosses a portion of the Yukon River drainage where the Iditarod River drains north to the Yukon. Glacial landforms have been recognized in the higher elevations of the Kuskokwim Mountains, such as in the Russian and Horn Mountains along the road alternatives (Meyer 1985; Kline and Bundtzen 1986). The proposed roads would begin at the mine site at an elevation of approximately 500 feet and descend to elevations of approximately 200 feet at the proposed Angyaruaq (Jungjuk) Port site and 150 feet at the BTC Port site, located 14 miles downstream from Aniak. The proposed road from the mine site follows the same route in both alternatives until the southwest end of Juninggulra Mountain, where the two routes diverge (Figure 2.3-42, Chapter 2, Alternatives). The proposed Angyaruaq (Jungjuk) route heads south from that point, traverses the north flank of the Horn Mountains, then runs east to the mouth of Jungjuk Creek on the Kuskokwim River. The proposed BTC access road heads west from the point of divergence, then southwest towards Molybdenum Mountain and Cobalt Creek, traverses the northwest flank of the Russian Mountains parallel to the Owhat River, then runs west across numerous streams flowing from the uplands of the Portage Mountains north of Aniak.

The riverine transportation route from the Angyaruaq (Jungjuk) and BTC port sites descends to an elevation of approximately 3 feet at Bethel. Bethel lies in the Yukon-Kuskokwim Coastal Lowlands, approximately 199 river miles downstream from the proposed Angyaruaq (Jungjuk) Port site and approximately 124 river miles downstream from the proposed BTC Port site. The proposed Bethel fuel depot and port would be located in the southwest section of the community, near the existing Bethel Fuel Sales pumphouse and tank farm on the western cut bank of the Kuskokwim River.

Proposed transportation facilities outside the immediate area include additional facilities at Dutch Harbor, approximately 460 miles south-southwest of the mouth of the Kuskokwim River, across Bristol Bay. The town of Dutch Harbor lies on Amaknak Island adjacent to the larger Unalaska Island, and the body of water referred to as Dutch Harbor lies between the two islands (Figure 2.3-8). In physiographic terms, the Dutch Harbor fuel storage depot is located in the Aleutian Islands sub-province within the larger Alaska-Aleutian province of the Pacific Mountain System physiographic division (Wahrhaftig 1965, 1994). Amaknak and Unalaska islands are bounded to the north by the Bering Sea and to the south by the Pacific Ocean. The Aleutian Islands form an arcuate chain of volcanoes (Aleutian Arc) extending westward from the southern Alaska Range (Aleutian Range) approximately 1,000 miles to its terminus at Attu Island. Volcanoes dominate the topography of the Aleutian Islands, with elevations varying from 2,000 to 9,000 feet (Wahrhaftig 1965).

#### 3.1.2.2.2 BEDROCK GEOLOGY

Upper Kuskokwim Area

Bedrock is exposed along the proposed transportation corridor upriver of Kalskag. The regional bedrock and structural geology of this area is similar to that described for the proposed mine site (Section 3.1.2.1.2).

The bedrock geology of the proposed Angyaruaq (Jungjuk) Road and port site is dominated by Late Cretaceous age Kuskokwim Group sedimentary rocks (Cady et al. 1955; Hoare and

Coonrad 1959a; Decker et al. 1994; Wilson et al. 1998). These rocks are intruded by a Late Cretaceous through Tertiary age igneous complex exposed in the Horn Mountains as far north as Juninggulra Mountain. The Horn Mountains igneous complex is an ancient volcanic center, made up of intrusive quartz monzonites, volcanic rhyolites, andesite, and granite porphyry (Hoare and Coonrad 1959a; Wilson et al. 1998).

The proposed BTC Road alternative follows the same path as the Angyaruaq (Jungjuk) route, until the point of divergence at Juninggulra Mountain. From Juninggulra Mountain west to the Iditarod River and in the Cobalt Creek area north of Russian Mountain, BTC route bedrock is dominated by sandstone, shale, and limestone of the Kuskokwim Group (Hoare and Coonrad 1959a; Bundtzen and Laird 1991; DMA 2007a; Reger et al. 2003c). Russian Mountain is recognized as a Late Cretaceous through Tertiary igneous complex similar to the Horn Mountains, but larger in size. The central portion of the proposed BTC Road traverses the north half of this igneous complex, which is dominated by basalt and andesite, with andesite to dacite flows and tuffs, and volcanic agglomerate (Bundtzen and Laird 1991). The north-trending Aniak-Thompson Creek Fault truncates rocks of the Kuskokwim Group and the Russian Mountains igneous complex near the Owhat River crossing (Decker et al. 1994; Wilson et al. 2013). West of the Owhat River, the Portage Mountains consist of Permian and Triassic age deformed volcanic and sedimentary rocks. The volcanic rocks here include flows, lahars (mud-flows), tuff, diabase, and andesitic breccia. The sedimentary rocks include graywacke sandstone, mudstone, calcareous conglomerate, and limestone.

Bedrock is exposed in bluffs and cut-banks along the Kuskokwim River upriver of Kalskag (Cady et al. 1955; Meyer 1985; Miller et al. 2002). River bluff exposures near Aniak exhibit deformation features that provide evidence of the Aniak-Thompson Creek Fault (Decker et al. 1994). There are no bedrock exposures in the Bethel community area (Dorava and Hogan 1995). Exploration test wells have recorded bedrock at depths greater than 500 feet in this area.

### Dutch Harbor

The general geologic setting of Dutch Harbor includes Tertiary age sedimentary and volcaniclastic rocks of the Unalaska Formation, intrusive rocks, and Quaternary age volcanic rocks of Makushin volcano (Drewes et al. 1961; Lankford and Hill 1979; Decker et al. 2012a). The bedrock geology of Amaknak Island includes hydrothermally altered andesite and basalt volcanic rocks (Lemke and Vanderpool 1995). The Unalaska Formation is the dominant bedrock on the portion of Unalaska Island adjacent to Dutch Harbor, and consists of volcanic breccias, flows, tuffs, and intermixed sedimentary rocks (Lankford and Hill 1979).

## 3.1.2.2.3 SURFICIAL GEOLOGY

### Kuskokwim River Corridor

Surficial deposits along the Kuskokwim River include coarse- and fine-grained alluvium, colluvium associated with hilly regions in the upper river, glacial moraines and associated drift (till)[6], fluvial floodplain deposits associated with the Kuskokwim River, and marine coastal deposits mixed with alluvial sediments (Karlstrom et al. 1964). The Kuskokwim River floodplain has been dominated by deposition of fluvial material since the last glacial advances

[6] Glacial drift or till is non-sorted, non-stratified, thin-layered material deposited by glacial action.

in the Alaska Range (Péwé 1975). Thick deposits of overbank flood, slack water deposits, and fluvial bar accretion deposits result from action associated with the Kuskokwim River in the Aniak area (Dorava 1994). Overbank flood deposits have been observed to be up to 33 feet thick and consist of silt and fine sand. Slack water deposits are found in sloughs and oxbow lakes and contain a higher proportion of organic material. Bar accretion deposits consist of sand and gravel with minor amounts of silt, which occupy the banks and bars of the Kuskokwim River. Marine coastal deposits south of Bethel include delta deposits and older coastal deposits, with a mixture of marine coastal and non-marine alluvium, including glacial drift.

## Jungjuk Road and Port

### *Surficial Geology*

Geotechnical studies conducted in 2005 through 2010 for the Donlin Gold Project inspected local baseline conditions in this area. These studies included excavation of 50 soil test pits, 37 exploratory borings, and borrow material site investigations. Fourteen of the borings were completed at the proposed Angyaruaq (Jungjuk) Port site and were advanced to depths ranging from 11.5 to 60 feet (DMA 2007b). Twenty-three boreholes advanced to depths ranging from 6 to 26 feet were completed along the access route from Juninggulra Mountain to the Angyaruaq (Jungjuk) Port site (RECON 2011a).

The stream channels and hill slopes of the proposed Angyaruaq (Jungjuk) Road and Port site are generally underlain by unconsolidated surficial deposits of colluvium and alluvium (Wilson et al. 1998). The floodplain of Crooked Creek west of the proposed mine site consists of a mixture of organic material, silt and sand up to 3 feet thick, overlying alluvial gravel above weathered bedrock. Ridge tops between Crooked Creek and the proposed Angyaruaq (Jungjuk) Port site contain frozen colluvial silt up to 6 feet thick over weathered broken bedrock. Accumulations of glacial till were also observed mantling bedrock in this area. The drainages of Getmuna and Jungjuk creeks contain alluvium and colluvium consisting of sandy and cobble gravel, silty sand, and silt layers up to 26 feet thick, over broken bedrock and in lower elevations frozen glacial till (RECON 2011a).

The proposed Angyaruaq (Jungjuk) Port site slopes gently to the south. The site is bordered to the southwest by Jungjuk Creek and to the south by the Kuskokwim River. Sixteen test borings advanced in 2005 through 2007 at the site indicate that alluvium is the dominant surficial deposit, consisting of silt and sand overlying gravel cobbles and gravelly sand. Silt and sand layers exhibit soft to medium dense consistency, and range in thickness from 6 to 45 feet (DMA 2007b). The underlying gravel exhibits medium to very dense consistency with thicknesses ranging from 5 to 16 feet.

### *Borrow Material Sites*

Based on the work performed, there would appear to be surficial materials of sufficient quality and quantity to supply the proposed project. Route inspections along the proposed Angyaruaq (Jungjuk) Road were conducted to investigate the consistency and quality of bedrock and surficial deposits for suitability as construction aggregate resources. For planning purposes, the maximum distance between material sites to be used for road fill purposes was 3.1 miles. The proposed volume of aggregate resource to be utilized from each site ranges from 50,000 to 2,500,000 cubic yards. Fourteen sites were investigated by excavating test pits to collect soil and rock samples for grain size distribution and rock quality analysis. The material sites north of Juninggulra Mountain also involved advancing boreholes by diamond core drilling methods to depths up to 290 feet to ascertain depth of weathering and extent of fracturing in the bedrock. The inspections identified mostly coarse gravel in Getmuna and Jungjuk Creek valleys and varying qualities of igneous and sandstone bedrock along the ridges. The material sites (MS) are designated MS01 through MS10 and MS12 through MS15 from north to south as described below (DMA 2007b; RECON 2011a):

- Sites MS01 and MS08 are located on ridge tops that contain moderately weathered, highly fractured granodiorite with potential utilization areas of approximately 35 and 42 acres, respectively, that will require blasting.
- Sites MS02 through MS04 are located on ridge tops with gentle slopes containing highly weathered and fractured quartz sandstone. Two of the three sites are likely rippable, and one may require blasting below weathered bedrock. These have potential utilization areas of approximately 6 to 19 acres each.
- Site MS10 is located on a level alluvial plain in the Getmuna Flats area between the north and south forks of Getmuna Creek. It contains glaciofluvial outwash gravel alluvium that covers a potential source area of 205 acres. The coarse gravel at this site was found to be good quality aggregate suitable for use in producing concrete.
- Sites MS05 through MS07, and MS09 are located on moderate slopes that contain moderately weathered volcanic rock (rhyolite), with potential utilization areas of approximately 5 to 25 acres each that will require blasting.
- Site MS11 testing revealed poor quality rock; the site was removed from further consideration.
- Sites MS12 through 14 are located south of Basalt Pass on moderate slopes that contain basalt, with a total potential utilization area of approximately 100 acres that will require blasting. Physical testing indicates the rock from these sites is of high quality for a potential source of aggregate. Site MS13 is located in a section of the access road where a proposed bedrock cut extending approximately 65 feet is planned. The gravel alluvium resource from MS10 is planned for mixing with the basalt from MS12 through MS14 to create suitable aggregate for producing concrete.
- MS15 is located on a sedimentary ridge top. The rock at this location is highly fractured and weathered siltstone and greywacke. Blasting is likely to be required. This material could be used for crushed aggregate.

<u>Birch Tree Crossing Road and Port</u>

*Surficial Geology*

Surficial deposits in the upland valleys and stream courses along the route of the proposed BTC Road generally include alluvium in the larger drainages and their associated tributary streams, and colluvium on the hill slopes (Karlstrom et al. 1964; Reger et al. 2003c). North of the Russian Mountains, incised channels that cut through the igneous bedrock contain a variety of glacial till, rock glaciers[7], colluvium (talus), and alluvium (Bundtzen and Laird 1991). In the

[7] A rock glacier is a mass of broken rock that moves down a sloping valley under its own weight or by the action of frost or interstitial ice.

southeastern portion of the Portage Mountains the primary surficial deposit is colluvium (Reger et al. 2003c).

Geotechnical studies conducted in 2007 for the Donlin Gold Project inspected local baseline conditions along the proposed BTC Road corridor and port site. These studies included 92 exploratory borings advanced to depths ranging from 3.5 to 59 feet, and 37 material sites investigated for construction aggregate resource. The predominant surficial geologic units encountered along the BTC Road alternative during the geotechnical studies include the following (DMA 2007a; RECON 2007a):

- Colluvium and loess deposits associated with ridges and side slopes generally consist of silt, gravelly silt, and silty gravel overlying weathered bedrock, and range from less than 5 feet to more than 20 feet thick. Deposits are generally thinner along the ridges and uplands west of Juninggulra Mountain, and thicker in the western part of the route along the lower slopes of the Russian Mountains and in the Portage Mountains.
- Glacial outwash deposits, consisting of sandy and silty gravel and gravelly sand, occur beneath colluvium and loess along the west slope of the Russian Mountains.
- Alluvium ranges from silt and silty gravel in smaller drainages, to thick interbedded deposits of coarser gravel, sand, and silt in larger drainages -- such as Iditarod and Kaina creeks and the Owhat River. Alluvial deposits in Ones Creek near the Kuskokwim River reach more than 59 feet thick.
- Muskeg and bog deposits contain thick organic silt, silt, and peat to over 20 feet deep in some areas.

The BTC Port site slopes gently to the southeast, bordered by hills to the west and by Ones Creek to the east. The closest borehole to this site, located about 0.5 mile to the northeast along the road alignment, encountered a thick sequence of frozen sandy, gravelly silt to depths over 27 feet (DMA 2007a), material likely associated with loess or colluvium from the lower hill slopes and Kuskokwim floodplain alluvium.

*Borrow Material Sites*

Material sites along the first 11 miles (northeast end) of the proposed BTC route would be the same as those described above for the proposed Angyaruaq (Jungjuk) Road (MS01 through MS06). Thirty-seven additional material sites were investigated for construction aggregate resource along the BTC route from Juninggulra Mountain to the proposed BTC Port site. These are designated MS16 through MS52, numbered from east to west. The proposed volume of aggregate resource to be utilized from each site ranges from 20,000 to 1,500,000 cubic yards, and consists of the following (DMA 2007a; RECON 2007a):

- Roughly two-thirds of the 37 sites contain highly fractured and weathered sedimentary rock consisting of graywacke sandstone/siltstone. Ten of these sites covering approximately 339 acres appear rippable, and 14 sites covering 425 acres would require blasting;
- Eight quarry sites contain volcanic rock consisting of weathered and fractured rhyolite or basalt. Together these sites total about 294 acres and would require blasting;

- Five gravel borrow sites are located within alluvial floodplains. Four of these are associated with abandoned outwash plains of meandering streams along the north and west slopes of the Russian Mountains, and one is located in the Owhat River floodplain. These borrow sites cover a total of about 164 acres.

Bethel Port

The surficial geology of the Bethel Port site is dominated by alluvial deposits of the Kuskokwim River floodplain and reworked silt in upland deposits (Hoare and Coonrad 1959b; Stevens et al. 2003; Wilson et al. 2013). The floodplain alluvium consists of mainly silt, sand, and gravel intermixed with fragments of wood and peat, but may also include beach sand deposits, clay-rich silt from estuarine deposits, and fine-grained wind-blown (eolian) sand. The upland deposits are separated from floodplain deposits by low erosional scarps, and are characterized by a surface consisting of large and small thaw lakes. The upland materials include reworked silt, sandy silt, and bog deposits (Wilson et al. 2013).

Dutch Harbor

Surficial geologic units at Unalaska and Amaknak Islands consist of alluvium, glacial till, and slope deposits (Karlstrom et al. 1964). The majority of the material is comprised of disintegrated volcanic rock, Pleistocene age glacial deposits, and air-fall tephra deposits from Makushin volcanic field. Surficial deposits on Amaknak Island near the Dutch Harbor airport consist of 2 feet of glacial till made up of gravel cobbles in a silt and clay matrix, overlain by volcanic air-fall ash deposits (Drewes et al. 1961; Lemke and Vanderpool 1995). Beach cliff faces bordering the harbor are dominated by talus cones (Lemke and Vanderpool 1995). Alluvial deposits of coarse sand and gravel occur in active stream channels.

#### 3.1.2.2.4 PALEONTOLOGICAL RESOURCES

There are several documented fossil locations along the Kuskokwim River between the communities of Aniak and Sleetmute (Cady et al. 1955; Elder and Box 1992; Elder and Miller 1991; Reuther et al. 2014). Plant macrofossils have been found in the Cretaceous age sandstones and siltstones of the Kuskokwim Group in the vicinity of the proposed mine access road and Port site. The non-marine strata within the Kuskokwim Group are known to contain abundant plant fossils, which are associated with a high potential for dinosaur tracks and skeletal remains in other areas of Alaska. No macrofossils have been found to date in nearby outcrops; however, exposures of non-marine Cretaceous rocks are limited in the area (Reuther et al. 2014). The occurrence of Late Cretaceous age marine bivalves has been documented upstream of the proposed Angyaruaq (Jungjuk) Port site and in the vicinity of Napaimute (Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013).

The BTC Road corridor also crosses sedimentary rocks of the Kuskokwim Group, although outcrops and fossil assemblages in the western part of the route are sparse (Bundtzen and Laird 1991). The BTC Port site lies partially on metasedimentary rocks of the Gemuk Group that are highly metamorphosed. While these rocks are correlated with fossiliferous limestone further west in the Portage Mountains, no fossils have been noted in Gemuk Group rocks in the vicinity of the BTC Port site (Bundtzen and Laird 1991; Hoare and Coonrad 1959a).

Pleistocene vertebrate fossils (mammoth, bison), that are considered "significant" to paleontological research in accordance with BLM classification terminology Table 3.1-1, have been found in river bluffs about 8 miles downstream of the Angyaruaq (Jungjuk) Port site. Similar stratigraphy exists along river bluffs further downstream near Napaimute, suggesting the potential for Pleistocene fossils in this area as well. Younger deposits in the vicinity of Jungjuk have low potential for paleontological remains (Reuther et al. 2014).

Vertebrate and invertebrate fossils have been documented in a sandstone, conglomerate, and turbidite member of the predominately volcanic Unalaska Formation southeast of Dutch Harbor. Fossils documented in these rocks, referred to as the Dutch Harbor Member of the Unalaska Formation, include early Miocene bivalves (*Chalmys* and *Pododesmus*) and bones and teeth of a marine mammal resembling a sea cow. The stratigraphic trend of the Dutch Harbor Member suggests that rocks underlying the port areas of Dutch Harbor are composed primarily of the non-fossiliferous upper volcanic sequence of the Unalaska Formation (Lankford and Hill 1979).

### 3.1.2.3 PIPELINE

#### 3.1.2.3.1 PHYSIOGRAPHY

<u>Alternative 2 – Donlin Gold's Proposed Action</u>

The proposed pipeline physical footprint includes the 315-mile-long right-of-way (ROW), terminal facilities, access roads, camps, storage yards, airstrips, and more than 60 borrow material sites. The proposed pipeline route crosses five physiographic sub-provinces: the Cook Inlet-Susitna Lowlands, the southern and west-central Alaska Range, the Tanana-Kuskokwim Lowlands, the Nushagak-Big River Hills, and the Kuskokwim Mountains (Figure 3.1-1) (Wahrhaftig 1965, 1994).

The proposed route begins along the western shore of Cook Inlet within the flat, glaciated Cook Inlet-Susitna Lowlands. The lowlands are bordered to the northwest by the foothills of the Alaska Range. From Beluga the route extends along the east flank of Little Mount Susitna, then continues westward paralleling the Skwentna River.

Continuing northwest along the Skwentna and Happy River valleys, the proposed pipeline route enters the rugged, northwest-trending glaciated mountains of the Alaska Range with elevations ranging from 7,000 to 12,000 feet. An unnamed pass at the highest point along the proposed route lies at an elevation of about 3,900 feet between Three-mile and So Long creeks. The climb up to the pass from Three-mile Creek Valley gains over 1,300 feet elevation in a distance of approximately 3 miles, and the descent on the north side of the pass is equally steep. The proposed pipeline corridor exits the Alaska Range along the Jones River Valley into the Tanana-Kuskokwim Lowlands, crossing the South Fork of the Kuskokwim River near Farewell.

The proposed route heads southwest across the rounded mountain tops of the Nushagak-Big River Hills province, with elevations ranging from 1,500 to 2,500 feet, until reaching the Kuskokwim River. At the Kuskokwim River crossing (Mile Post [MP] 238), the route continues westerly and enters the Kuskokwim Mountains sub-province. The west end of the proposed pipeline corridor traverses Anaconda Peak at an elevation of approximately 2,200 feet and ends at the proposed mine site at an elevation of approximately 500 feet.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B, an 18-inch diameter diesel pipeline would be constructed from Cook Inlet to the mine site to reduce diesel barging on the Kuskokwim River. The diesel pipeline would be buried and located in the same corridor proposed for the natural gas pipeline under Alternative 2 (Figure 2.3-14 in Chapter 2, Alternatives), with an additional 19-mile segment between Tyonek and the start of the proposed corridor for the natural gas line (Michael Baker Jr. 2013a), for a total of 334 miles. This additional segment would cross the Beluga River using horizontal directional drilling (HDD).

The affected environment for most of the Alternative 3B route would be the same as what is described under Alternative 2. The additional 19-mile segment is physiographically in the Cook Inlet-Susitna Lowlands (Figure 3.1-1). The lowlands are flat and formerly glaciated. The lowlands are bordered to the northwest by the foothills of the Alaska Range, and the west and south by Cook Inlet.

Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route

The Dalzell Gorge route diverges from the Alternate 2 alignment at approximately MP 106.5 in the 2-mile wide Happy River drainage for roughly 5 miles before turning northwest at Pass Creek in the upper reaches of Ptarmigan Valley. The general physiography at the mouth of Pass Creek consists of a narrow drainage valley with an elevation of approximately 2,700 feet bordered by rugged, steep mountainous terrain. The route climbs the Pass Creek drainage up to its headwaters at Rainy Pass Lake and the west side of Rainy Pass. From the mouth of Pass Creek, the route gains approximately 460 feet of elevation reaching Rainy Pass at an elevation of 3,160 feet. The route then descends the east side of Rainy Pass parallel to the Pass Fork of Dalzell Creek as the route enters the 2-two mile long Dalzell Gorge. Dalzell Gorge is characterized by steep, rugged terrain following the V-shaped Dalzell Creek drainage as it descends in elevation until emptying into the Tatina River drainage at an elevation of approximately 1,500 feet. The route crosses the Tatina River and then the South Fork of the Kuskokwim River near Rohn, then parallels the west bank of the South Fork Kuskokwim River as it heads toward the south side of Egypt Mountain and High Lakes at an elevation of approximately 1,700 feet before rejoining the Alternative 2 route at approximately MP 152.7.

### 3.1.2.3.2 BEDROCK GEOLOGY

Regional Setting

The regional geology of the western portion of the proposed pipeline corridor is similar to the geology of southwest Alaska as described for the proposed mine site area (Section 3.1.2.1.2), with primary bedrock consisting of the deep marine sequence of the Cretaceous age Kuskokwim Group (Wilson et al. 1998). The rocks of the Alaska Range are separated into sequences which include, from west to east, parts of the Farewell terrane known as Dillinger and Nixon Fork sub-terranes, and the Kahiltna assemblage (Decker et al. 1994; Bradley et al. 2003; Nokleberg et al. 1994; Wilson et al. 1998, 2013). The Upper Cook Inlet region consists of Mesozoic and Cenozoic age sedimentary, volcanic, and plutonic rocks. The plutonic rocks are associated with the Late Cretaceous and Tertiary age Alaska–Aleutian Range batholith, and the sedimentary and volcanic rocks are associated with the Early Jurassic age Talkeetna island arc (Wilson et al. 2012; Haeussler and Saltus 2011). These rocks are intruded and overlain by

Cenozoic volcanic rocks of the modern Aleutian magmatic arc (Wilson et al. 2012; Herriott et al. 2011). The west side of Cook Inlet is dominated by several active volcanoes, including Mount Spurr and Redoubt Volcano, located near the proposed pipeline corridor (Keith 1995; Schaefer 2012; AVO 2013).

There are two primary regional-scale structural features along the proposed pipeline corridor (Figure 2.3-33 in Chapter 2, Alternatives). The Denali-Farewell Fault system is the dominant morphological feature expressed along the northern flank of the Alaska Range. The southwest extent of the Castle Mountain-Lake Clark Fault system, and a sub-parallel splay off of that system called the Bruin Bay Fault, lie near the eastern end of the proposed pipeline route (Wilson et al. 2012; Hauessler and Saltus 2011; Koehler and Reger 2009, 2011). Seismic and other geologic hazards related to these faults are presented in Section 3.3, Geohazards and Seismic Conditions.

## Local Bedrock Geology

### *Alternative 2 – Donlin Gold's Proposed Action*

Sedimentary rocks of the Beluga Formation and plutonic rocks of Little Mount Susitna are exposed near the east end of the proposed pipeline route. The Miocene age Beluga Formation is exposed in the Chuitna River drainage near Tyonek and consists of non-marine sandstone, siltstone, carbonaceous shale, and coal. Beluga Formation rocks encountered in wells in the Tyonek to Beluga area at depths of 4,000 feet define the top of one of the primary gas-producing zones of the Cook Inlet Basin petroleum province (ADNR 2009b). Shallow bedrock was encountered on Little Mount Susitna in two geotechnical boreholes at depths of 3 to 12 feet (CH2MHill 2011b). Little Mount Susitna consists of Paleocene age granodiorite, tonalite, and monzonite dikes (Wilson et al. 1998, 2012).

Bedrock in the upper Skwentna River Valley consists of Cretaceous age sedimentary rocks of the Kahiltna sequence, Paleocene age granitic rocks, and Cretaceous to Paleocene age volcanic rocks (Wilson et al. 2012). The route is underlain by Kahiltna sequence rocks along Happy River, and Cambrian to Devonian age shallow marine carbonate rocks of the Dillinger sequence in the Tatina River drainage (Bundtzen et al. 1997). From the Jones River region southwest, bedrock consists of predominantly Dillinger sequence rocks until the Big River crossing, where Nixon Fork, Kuskokwim Group, and Kahiltna sequence rocks are exposed nearby (Bundtzen et al. 1997; Wilson et al. 1998). From Big River to the George River crossing, the proposed pipeline corridor crosses rocks of the Kuskokwim Group until reaching the end of the proposed pipeline at the proposed mine site (Wilson et al. 1998).

### *Alternative 3B – Reduced Diesel Barging: Diesel Pipeline*

Under Alternative 3B, the additional 19-mile segment between Tyonek and the start of the proposed corridor for the natural gas line is similar to what is described under Alternative 2 for the east end of the pipeline route. The additional segment is underlain by the Beluga Formation of non-marine sandstone, siltstone, carbonaceous shale, and coal. Shallow bedrock was encountered on Little Mount Susitna in two geotechnical boreholes at depths of 3 to 12 feet (CH2MHill 2011b). Little Mount Susitna consists of Paleocene age granodiorite, tonalite, and monzonite dikes (Wilson et al. 1998, 2012).

*Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route*

The general bedrock geology along the Alaska Range section of Alternate 6A consists predominantly of marine sedimentary rocks of the Upper Jurassic to Cretaceous age Kahiltna sequence (Wilson et al. 1998, 2012). The Kahiltna sequence is made up of thin beds of black shale and dark gray sandstone with minor amounts of conglomerate, black chert, and limestone. The sedimentary rocks are moderately deformed and locally exhibit strong metamorphic textures. In this region of the Alaska Range, the Kahiltna sequence is very similar to the Kuskokwim Group to the west where the mine site is located (Flanigan 2011). Both rock sequences are recognized to have similar lithology and character, and some studies suggest they should be identified as the same rock unit (Wilson et al. 2012; Flanigan 2011; CH2MHill 2011b).

Isolated plutons of Paleocene to Late Cretaceous age intrusive rocks occur in the eastern portion of the Dalzell Gorge route and intrude the sedimentary Kahiltna sequence rocks. The Late Cretaceous age intrusive rocks include fine- to coarse-grained granite, granodiorite, and quartz monzonite. Smaller isolated stocks of Paleocene age intrusive rocks intrude through the Kahiltna sequence and consist of medium-grained granite, syenite, tonalite, quartz monzonite, quartz diorite, granodiorite, and minor diorite (Wilson et al. 2012).

### 3.1.2.3.3 SURFICIAL GEOLOGY

#### Regional Setting

Surficial units in the Cook Inlet coastal lowlands consist of Quaternary age deposits that record the advance and retreat of glaciers in the Cook Inlet Basin. The upper northwest shorelands of Cook Inlet contain glacial till deposits of gravel, sand, silt, and clay (ADNR 2009a; Karlstrom et al. 1964). From Tyonek to Little Mount Susitna, the area is dominated by Upper Pleistocene age glacioestuarine deposits and Holocene and Upper Pleistocene age alluvial fan deposits that transition into colluvium and talus beyond Little Mount Susitna (Reger et al. 2003b; Wilson et al. 2012). From Little Mount Susitna to the drainages of the Skwentna and Happy rivers, the predominant unconsolidated material includes Upper Pleistocene age glacial moraine and kame deposits, Holocene age floodplain alluvium and terraces, and Upper Pleistocene age glacial outwash plains and fans (Wilson et al. 2012).

The central Alaska Range is dominated by: glaciofluvial, colluvial, and alluvial deposits in steep mountainous terrain; glacial moraines and associated drift (till) in higher elevations; and fluvial, alluvial and colluvial deposits in the hilly regions of drainages on the north side of the Alaska Range (Wilson et al. 1998). On the North flank of the Alaska Range, from the South Fork Kuskokwim River to the Tatlawiksuk River, the proposed pipeline corridor crosses predominantly alluvial fan and floodplain material that has been deposited in the Kuskokwim River Basin since the last glacial advances of the Alaska Range (Péwé 1975). From there to the proposed mine site, the upland valleys and stream courses of the Kuskokwim Mountains contain alluvium in the larger drainages and tributary streams, and colluvium on hill slopes (Karlstrom et al. 1964).

## Local Surficial Geology

### *Alternative 2 – Donlin Gold's Proposed Action*

In 2010 and 2013, geotechnical studies were conducted along the corridor to investigate local baseline conditions, collect and analyze soil samples for physical characteristics, and support development of terrain maps. These investigations included: the advancement of 530 exploratory boreholes, using direct push technology, to depths up to 27 feet; 50 test pits excavated to depths up to 8 feet along the western segment of the route; and geophysical surveys and 15 air-rotary boreholes to depths up to 135 feet at six major river crossings to estimate the depth of bedrock and evaluate suitability of HDD methodology for pipeline installation (BGC 2013a, 2013c; CH2MHill 2011b).

Terrain mapping conducted by CH2MHill (2011b) identified five classifications of surficial deposits in GIS along the proposed pipeline route based on geologic origin and process:

- *Alluvial and fluvial* deposits consisting of sand and gravel, fine to coarse gravels, and sands with some silt;
- *Colluvial* deposits consisting of unsorted material with a wide range of particle sizes, including talus and landslide debris;
- *Lacustrine and bog* units consisting of peat and organic silt and clay deposited in lakes and ponds;
- *Glacial* deposits consisting of (1) outwash fans, terraces, and broad plains near ancestral glacial margins, consisting of stratified drift of gravel with sand and silt lenses, and glaciofluvial gravel, sand, and silt; and (2) till consisting of unsorted mixtures of mostly silt with gravel, sand, and clay deposited by glacial ice; and
- *Residual* deposits consisting of in-place weathered bedrock.

Additional terrain mapping completed by BGC (2013a) between about MP 75 and MP 150 classified surficial deposits based primarily on slope stability process: debris flow, slow mass movement (creep), rockfall, rock or debris avalanches, or river erosion (see Section 3.3).

The following paragraphs summarize the types of surficial deposits present along the proposed pipeline route from east to west (BGC 2013a, 2013c; CH2MHill 2011b):

- From MP 0 to MP 75, surficial units consist of glacial ground moraine and outwash deposits near the shore of Cook Inlet; sloping alluvial plain material on the lower slopes of Little Mount Susitna, which consist of reworked glacial till incised by active mass wasting and storm event slope erosion; and in the Skwentna River valley, glacial outwash, alluvial creek channel fill, hummocky ground moraines with isolated outwash terraces, and low elongate glacial drumlin-type hills surrounded with swamp bogs and small thaw lakes.
- From MP 75 to MP 150, surficial deposits consist of glacial outwash and fluvial sand and gravels of the Skwentna and Happy river valleys, debris flow material and bank slope colluvium through the unnamed pass and down to the South Fork of the Kuskokwim River, into broad glaciofluvial plain leading to the north edge of the Alaska Range (Figure 3.3-4, Section 3.3, Geohazards and Seismic Conditions). The majority of the valley bottoms consist of glacial till poorly graded silty gravels, then sandy gravel

alluvium in the main river bed and stream floodplains. Lower valley slopes consist of colluvium talus and alluvium of silt and sand and glacial till ground moraine.

- Near MP 150 south of Farewell, lies a surficial mineral deposit consisting of yellowish brown, hydrothermally altered glacial drift with distinct silicrete (silica) or ferricrete (iron) alteration rinds. These deposits, known as the Farewell Mineral Licks, and frequented by buffalo and moose, consist of three circular exposures, up to 120 feet in diameter, that occur over a 0.5 mile distance along the trace of the Denali-Farewell Fault (Bundtzen et al. 1997; Owl Ridge 2013a).
- From MP 150 to MP 225, the proposed pipeline corridor traverses the Kuskokwim Lowlands consisting of sand and gravel alluvial fans and glacial outwash; several large braided streams that flow northward draining the Alaska Range; and terrain of past glaciations characterized by coarse- to fine-grained moraine and till deposits, hummocky silt dominated kames, large broad river drainages, and sporadic boulders. Terminal moraines[8] at MP 185 and MP 195 form prominent morphological features in this area. The area west of Big River contains remnants of a stagnated large valley glacier including glacial till kames and kettle lakes, hummocky hills, and braided floodplain channels. The moraine at MP 195 marks an abrupt change to reworked ground moraine and recent outwash channel deposits related to the Big River glacier and older glacial deposits. The rounded hilltops west of Tatlawiksuk River at MP 217 contain colluvium consisting of silt, sand, and gravel.

From MP 225 to MP 315, surficial deposits consist of mostly colluvium from mass wasting and bedrock weathering on ridges and hilltops of the Kuskokwim Mountains. The colluvium consists of silt, sand, angular gravel, and degraded bedrock. The lower hill slopes have thicker accumulations of these materials. The majority of the alluvial deposits in this area are composed of thick accumulations of glaciofluvial material.

#### *Alternative 3B – Reduced Diesel Barging: Diesel Pipeline*

Under Alternative 3B, the additional 19-mile segment between Tyonek and the start of the proposed corridor for the natural gas line is similar to what is described for the east end of Alternative 2. The additional segment is underlain by glacial ground moraine and outwash deposits.

#### *Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route*

Surficial deposits along the Dalzell Gorge segment of Alternative 6A are found within the flat-lying drainage basins and the slopes bordering stream channels. In the low-lying areas, surficial deposits include Holocene age alluvium along the major stream courses, consisting of sand and gravel from actively reworked deposits in bars and low terraces; outwash from present day glaciers; and small alluvial fans (Wilson et al.2012). The stream alluvial deposits are intertwined with Late Pleistocene age outwash from glacial moraines, consisting of well-bedded and sorted gravel and sand, and major glacial moraine and kame deposits of poorly bedded and sorted gravel and sand.

Holocene and Late Pleistocene age landslide and colluvial deposits, derived from downslope movement, occupy slopes bordering narrow stream channels. The landslide and colluvial

[8] Terminal moraines identify the furthest advance of a glacier.

deposits consist of mixed fragments of various sizes of bedrock, unconsolidated sand and gravel, and minor amounts of clay and organic materials (Wilson et al.2012). A 1.8-mile segment of the Dalzell Gorge route would be installed using HDD methodology to avoid these deposits and steep terrain (CH2MHill 2011b).

## Material Sites

### *Alternative 2 – Donlin Gold's Proposed Action*

Proposed pipeline construction estimates indicate that roughly 800,000 to 1,000,000 cubic yards of aggregate would be needed for pads, camps, and airstrips; and that an additional 700,000 to 1,000,000 cubic yards would be required for the access roads. Approximately 55,000 cubic yards would be required for trench backfill in ice-rich soils (SRK 2013b). Sixty-nine potential material sites were identified for construction aggregate resources along the pipeline corridor from Beluga to the proposed mine site. Of these, 21 are on federal (BLM)–managed land and the remainder on state or other lands (Table 2.3-27, Chapter 2, Alternatives). Material sites on BLM-managed lands lie between MP 174 and MP 299 on the north flank of the Alaska Range and in the Kuskokwim Hills regions.

The locations of borrow sites along the pipeline route are presented in Appendix D. These are designated MS00 through MS63 from east to west (with some site numbers used multiple times followed by letter designations), and contain the following materials (CH2MHill 2011b; SRK 2013b):

- Twenty-six sites contain sedimentary rock, and one site near Little Mount Susitna contains granitic rock. Two of the sedimentary rock sites contain a combination of bedrock and gravel. The bedrock quarry sites have a total potential utilization area of approximately 500 acres. The largest of these are located in the Kuskokwim Hills. It is unknown how many of these sites would require blasting. Two of three material sites located in similar Kuskokwim Group sedimentary rocks along the mine access road were found to be highly weathered, fractured, and rippable, suggesting that many of the pipeline material sites could be rippable. The granitic rock material site is likely to require blasting.
- Eighteen sites contain alluvial gravel, and have a total potential utilization area of approximately 330 acres. The largest of these, each with potential usage greater than 150,000 cubic yards, are located in the Cook Inlet Lowlands, Skwentna River Valley, and near the South Fork Kuskokwim crossing.
- Twenty-five sites contain other types of gravel deposits, and have a total potential utilization area of approximately 250 acres. The largest of these, each with potential usage greater than 150,000 cubic yards, are located on the lower slopes of Beluga Mountain, in alluvial fan material near Farewell, and in glacial deposits near Big River.

### *Alternative 3B – Reduced Diesel Barging: Diesel Pipeline*

Under Alternative 3B, the additional 19-mile segment between Tyonek and the start of the proposed corridor for the natural gas line is similar to what is described under Alternative 2 for gravel material sites. There would be up to five additional material sites containing glacial gravel deposits along this section of Alternative 3B.

*Alternative 6A – Modified Natural Gas Pipeline: Dalzell Gorge Route*

A total of 11 material sites were identified along the Dalzell Gorge section of Alternate 6A, all but one of which contain alluvial gravel (SRK 2013b). The Airfield Quarry at MP 108.5 would utilize sedimentary bedrock exposed along a ridge and has a potential utilization area of approximately 22 acres. The 10 alluvial gravel sites are located predominantly in stream channels and have a total potential utilization area of approximately 107 acres. The largest utilization would be from Dalzell Creek at MP 123.6 that has a potential utilization area of approximately 29 acres and would be used for constructing a camp, laydown yard, and airstrip (SRK 2013b).

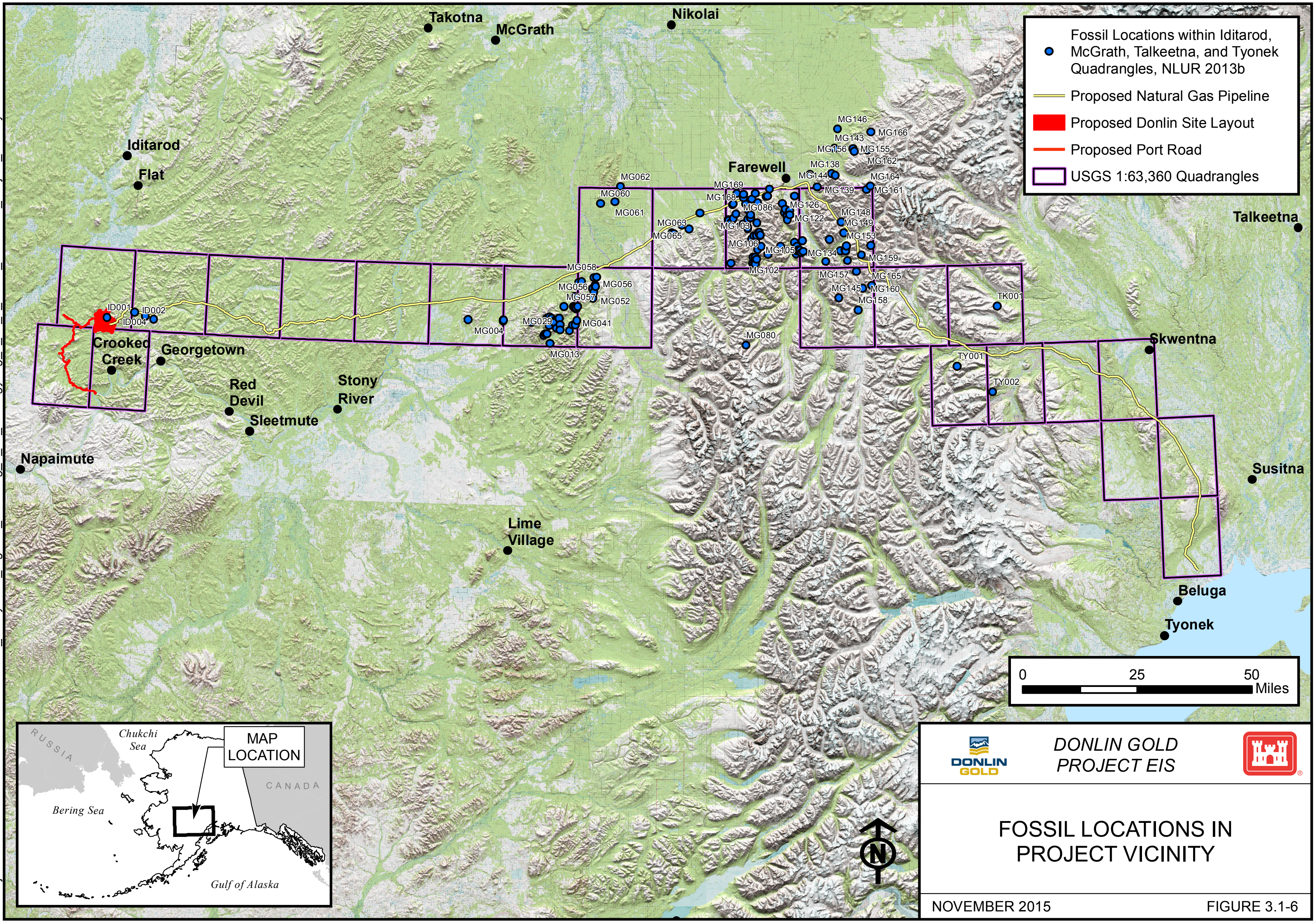
### 3.1.2.3.4 PALEONTOLOGICAL RESOURCES

The proposed pipeline corridor would cross a number of potential fossil-bearing sedimentary formations. Fossil localities have been reported on both federal and non-federal (state and other) lands along the proposed pipeline corridor; however, approximately 95 percent of the reported occurrences are on non-federal lands (Druckenmiller et al. 2013). Federal lands were assessed as having known or potential fossil localities without providing specific counts (Jacobus and Druckenmiller 2013). These were given potential fossil yield ratings based on the PFYC classification system shown in Table 3.1-1. The results for both non-federal and federal lands are listed in Table 3.1-2, and the results for non-federal lands are shown on Figure 3.1-6. Fossil occurrences along the proposed pipeline corridor for both non-federal and federal lands are summarized below.

<u>Alternative 2 – Donlin Gold's Proposed Action</u>

*Upper Skwentna River Area:* Fossil localities in the Tyonek and Talkeetna quadrangles are associated with Tertiary age Kenai Group coal occurrences and Cretaceous age marine sedimentary rock. Based on comparison to the geologically similar fossil-bearing Chickaloon Formation, the Kenai Group has the potential to contain fossils of plant impressions, petrified wood, amber; and trace fossils of invertebrates and vertebrates. Fossils in the deformed and locally metamorphosed Cretaceous rock include bivalves, and potentially other marine invertebrates. Outcrops of these rocks are generally absent along the proposed pipeline corridor due to the prevalence of Quaternary surface deposits; however, the potential exists to encounter fossil-bearing substrates below the Quaternary deposits, or fossils amongst the Quaternary glacial outwash and till materials.

*Alaska Range:* The McGrath quadrangles (1:63,360) represent the northern portion of the Alaska Range that coincide with the proposed pipeline footprint. Most fossil bearing strata occurs on State lands consisting primarily of marine sediment. However, floral and faunal remains of late Cretaceous and Tertiary age have been documented along ridgelines in McGrath A-6 and A-6 quadrangles, in addition to well preserved Tertiary age plant fossils in the McGrath B-2 and B-3 quadrangles. The Dillinger Terrane consisting of deep water marine rock contains numerous graptolite-bearing fossil locales of Cambrio-Ordovician to Late Silurian age along the northern portion of the Alaska Range. Most of the known fossil localities in the southeast corner of the McGrath quadrangle (1:250,000) in the Alaska Range are associated with Cretaceous age Kahiltna Flysch sequence rocks. This sequence consists of locally metamorphosed and intensely deformed marine sediments bearing marine invertebrates which include bivalves.




*DONLIN GOLD PROJECT EIS*

FOSSIL LOCATIONS IN PROJECT VICINITY

NOVEMBER 2015

FIGURE 3.1-6

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**Table 3.1-2: Fossil Localities along Pipeline Corridor**

| Location (1:63,360 USGS Quadrangle) | Non-Federal Lands | | Federal Lands | |
|---|---|---|---|---|
| | Fossil Locality Count | Percent of Total | Fossil Presence | Potential Fossil Yield Classification (PFYC) |
| Tyonek D-6/7 | 2 | 1.1 | n/a | n/a |
| Talkeetna A-5 | 1 | 0.7 | n/a | n/a |
| McGrath A-1 | 4 | 2.3 | n/a | n/a |
| McGrath B-1 | 16 | 9.0 | n/a | n/a |
| McGrath B-2 | 68 | 38.4 | n/a | n/a |
| McGrath B-3 | 5 | 2.8 | KFL | 3a |
| McGrath B-4 | 3 | 1.7 | PFL | 3a |
| McGrath A-4 | 13 | 7.3 | KFL | 3a |
| McGrath A-5 | 60 | 33.8 | KFL | 2 |
| McGrath A-6 | 1 | 0.7 | X | X |
| Iditarod A-1 | X | X | X | X |
| Iditarod A-2 | X | X | X | X |
| Iditarod A-3 | 0 | 0 | PFL | 3b |
| Iditarod A-4 | 3 | 1.6 | KFL | 3b |
| Iditarod A-5 | 1 | 0.6 | KFL | 3b |
| **TOTAL** | **177** | **100** | - | - |

**Notes:**

KFL =known fossil localities
PFL =potential fossil localities
n/a = no large proportion of federal lands in quadrangle along corridor
X = data gap

**PFYC System:**

2 = Not likely to contain fossils, or contains abundant specimens for research.
3a = Geologic units with moderate fossil potential.
3b = Geologic unit with unknown fossil potential; further reconnaissance and research suggested.

Sources: Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013.

*Western Kuskokwim Hills:* Known fossil localities in the Iditarod quadrangles are associated with Cretaceous age sedimentary sandstones and siltstones of the Kuskokwim Group, and include plant fossils, coal, and black organic residue. Skeletal and trace (footprints) dinosaur fossils could also be present in select geologic units based on geologic similarities with other Cretaceous age depositional settings; however, there are poor exposures in this area and this has not been confirmed. Cretaceous age terrestrial fossils may also exist in the Iditarod A-3 quadrangle based similar geologic conditions in the adjacent quadrangle to the north. Insufficient paleontological information is available for the Iditarod A-1 and A-2 quadrangles near the mainstem Kuskokwim River to assess whether fossils are present or suitable geologic conditions for their occurrence exist, although the general extent of Cretaceous rocks mapped in this region by Wilson et al (1998) suggest their potential may be similar to other nearby quadrangles.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B, the additional 19-mile segment between Tyonek and Beluga would be the same as what is described under Alternative 2 for the east end of the route with regard to fossil potential in Quaternary surficial deposits.

Alternative 6A – Modified Natural Gas Pipeline: Dalzell Gorge Route

As presented above under Alternate 2, numerous paleontological occurrences are recognized in the McGrath and Tyonek quadrangles that include the Alternate 6A route (Figure 3.1-6). Thus, the paleontological occurrences for the Dalzell Gorge section of Alternate 6A are the generally same as those found in Alternate 2.

#### 3.1.2.4 CLIMATE CHANGE

Climate change is affecting resources in the EIS Analysis Area and trends associated with climate change are projected to continue into the future. Section 3.26.3, Climate Change, discusses climate change trends and impacts to key resources in the physical environment including atmosphere, water resources, and permafrost. Effects from climate change to physiography, bedrock, surficial geology, and paleontological resources are limited to date, and future effects are generally associated with changes in permafrost and increased risk of erosion (discussed in Sections 3.26.3.3 and 3.26.3.2, Climate Change).

### 3.1.3 ENVIRONMENTAL CONSEQUENCES

The criteria for analyzing environmental impacts to geological resources are based on the criteria described in Table 3.1-3.

**Table 3.1-3: Impact Criteria for Effects on Geological Resources**

| Type of Effect | Impact Component | Effects Summary | | |
|---|---|---|---|---|
| **Changes to Physical Resource Character (General Physical Resources)** | Magnitude or Intensity | **Low**: Changes in resource character may not be measurable or noticeable. | **Medium**: Noticeable changes in resource character. | **High**: Acute or obvious changes in resource character. |
| | Duration | **Temporary**: Resource would be reduced infrequently, but not longer than the life of the project construction, and would be expected to return to pre-activity levels at the completion of the construction activity. | **Long-term**: Resource would be reduced through the life of the project and would return to pre-activity levels long-term (from the end of construction through the life of the mine, and up to 100 years). | **Permanent**: Chronic effects; resource would not be anticipated to return to previous levels. |
| | Geographic Extent | **Local:** Impacts limited geographically; discrete portions of the EIS Analysis Area affected. | **Regional:** Affects resources beyond a local area, potentially throughout the EIS Analysis Area. | **Extended:** Affects resources beyond the region or EIS Analysis Area. |

**Table 3.1-3: Impact Criteria for Effects on Geological Resources**

| Type of Effect | Impact Component | Effects Summary | | |
|---|---|---|---|---|
| | Context | **Common:** Affects usual or ordinary resources; not depleted or protected by legislation. | **Important:** Affects depleted resources within the locality or region or resources protected by legislation, or resource hazards governed by regulation. | **Unique:** Affects unique resources or resources protected by legislation. |

In evaluating negative and positive impacts to geological resources, relevant factors for this project include:

- The area of the impacts. Larger project footprints change and modify the landforms over a bigger area. Areas covered with tailings piles or waste rock may no longer be accessible for other uses.
- Permanent decrease in the volume of resources remaining. For example, excavation and processing of the ore and aggregate removes these resources from the Project Area.
- Disruption/changes to landforms. This predominately consists of slope and elevation changes. This can also impact geotechnical stability.
- Modifications or reduction in unique resources. This could include a negative impact of the loss of high value fossils, or a beneficial impact of mining ore, which supports the project's purpose and need.

### 3.1.3.1 ALTERNATIVE 1 – NO ACTION

There would be no construction and operations of facilities, and no extraction or reduction of existing mineral resources or aggregate. On-going geological exploration would cease. Thus, there would be no direct or indirect effects on bedrock geology, mineral resources, surficial geology, aggregate resources, or paleontological resources from this alternative.

Not developing the mineral resources would contradict the objective of Calista in selecting these lands for their mineral development potential pursuant to ANCSA.

### 3.1.3.2 ALTERNATIVE 2 – DONLIN GOLD'S PROPOSED ACTION

#### 3.1.3.2.1 BEDROCK GEOLOGY AND RELATED RESOURCES

<u>Mine Site</u>

The Donlin Gold Project involves the construction, operations, reclamation, and closure of an open pit, hard-rock gold mine that would produce approximately 30 million ounces of gold over an estimated operational mine life of 28 years. Construction of the Donlin Gold Project would take approximately 4 years. The proposed mine would be a conventional truck-shovel open pit operation. Predominantly sulfide ore would be processed to produce an average of over 1 million ounces of gold annually. The ultimate pit would target the Lewis and ACMA deposits and extend to a depth of approximately 1,850 feet from the highest point of the pit wall to final pit bottom. The mine would operate year-round and process an average of approximately 59,000 tons of ore per day.

*Construction*

As a result of Alternative 2, disturbance of bedrock would occur during site preparation, pre-stripping, haul road construction, aggregate production, and ramp-up to operations (pre-production across several areas within the overall mine site footprint. Construction of the Tailings Storage Facility (TSF) would potentially require excavation of weathered bedrock across approximately 2,400 acres. The initial ACMA pit area that would be excavated during site preparation and pre-production covers approximately 80 acres (SRK 2012e). The process facilities, power plant, and fuel storage areas, which encompass approximately 480 acres, may require grading of a bedrock ridge. Two bedrock material sites located on the ridges above the mine encompass a total of approximately 240 acres.

During pre-production, approximately 9 million tons (Mt) of ore would be blasted, excavated, and stockpiled for processing (SRK 2012e). Approximately 30 Mt of waste rock would be generated from blasting and excavating the ore during pre-production and placed in the Waste Rock Facility (WRF). Minor blasting of the bedrock material sites may also occur during construction. Approximately 1.5 Mt of waste rock would be utilized to construct foundation pads, nearly 1.6 Mt would be used to construct rock drains, and an additional 1 Mt would be used to construct roads. At the end of construction roughly 15 Mt of waste rock would be utilized for the construction of the TSF dam (SRK 2012e).

Potential direct impacts from construction activities and surface disturbances would expose bedrock at the mine site to erosion from potential channelization of runoff. The effects of erosion and mass wasting, as well as planned mitigation to address these issues, are covered in Sections 3.2, Soils, and 3.3, Geohazards and Seismic Conditions, respectively.

Based on impact criteria presented in Table 3.1-3 direct impacts to bedrock during construction of Alternative 2 would be permanent and high intensity due to ground disturbances and reshaping of landforms by blasting, excavation, and direct removal of weathered bedrock, waste rock, and ore. Landforms that would be affected include hills and ridges (Section 3.1.2.1.1, Physiography). The effects would be localized as they would be limited to discrete portions of the mine footprint. While most geologic resources impacted by the proposed project are considered common in context, the ore excavated during construction is a unique economic resource driving the purpose and need of the project.

*Operations and Maintenance*

Potential direct impacts from Alternative 2 during operations would involve processing of 505 Mt of ore that would be blasted, excavated, and stockpiled for processing (SRK 2012e). Approximately 2,765 Mt of waste rock would be blasted and excavated from the pit. A small amount of this waste rock would be used for construction (103 Mt), or to backfill the pit (424 Mt), but most would be placed in the WRF (2,232 Mt), which would reach an ultimate elevation of about 1,700 feet at the end of operations, a difference in elevation up to about 600 feet higher than original topography. The shape of the WRF has been designed to conform to the surrounding natural landforms to the extent possible, and would not rise above surrounding topography. Minor blasting and excavation of bedrock at material sites may occur during operations. Approximately 9 Mt of waste rock would be used to construct rock drains. The ultimate pit size at the end of operations would extend across about 1,462 acres. Bedrock beneath the WRF and TSF that would be covered during operations and inaccessible for future uses (such as mineral or aggregate extraction) encompasses about 4,583 acres.

Similar to the construction phase, potential direct impacts on bedrock during operations would be localized, permanent, and of high intensity due to blasting, excavation, and removal/alteration of bedrock, a resource that ranges from common to unique depending on grade of the mineral resource.

*Closure, Reclamation, and Monitoring*

The Donlin Gold Project would utilize a “design for closure” concept for reclamation and closure planning at the mine site. Design for closure incorporates methods for safe and efficient closure of the mine as an integral part of the mine design and operations. Implementing design for closure can have the effect of minimizing disturbance and the re-handling of materials. For example, some reclamation activities would be conducted concurrently with the operations phase of the project wherever possible in areas no longer required for active mining (SRK 2012a). Inactive or dormant areas of the WRF would be graded and contoured to aid in development of the vegetative cover and minimize impacts on other resources (e.g. water quality, soil erosion).

During closure and reclamation activities, roughly 400 Mt of waste rock would be used to backfill portions of the pit (SRK 2012e), resulting in final elevation differences between the surrounding ground surface and the bottom of the backfilled pit of up to 600 feet. Potential direct impacts on bedrock from closure and reclamation activities would involve grading and contouring of the WRF, TSF, freshwater ponds, contact water ponds, road cuts and fills, power plant, ore processing facilities, safety berms around the pit rim, and areas of the pit designed to allow human access. Bedrock slopes and benches within the interior of the pit would not be graded. Haul roads in and around the pit would be smoothed of berms, except those necessary for erosion control and safety (SRK 2012f). Other road cut and fill areas would be contoured to match surrounding landforms as much as feasible.

The WRF cover would be designed to minimize infiltration through potentially acid generating (PAG) materials (discussed in Section 3.7, Water Quality). The cover itself would consist of non-PAG materials. At the completion of contouring, a layer of unconsolidated material from the North and South Overburden Stockpiles would be spread over the surface and overlain with an additional layer of growth media (topsoil and overburden). Closure of the TSF would include the reuse of non-PAG waste rock for cover material, overlain by overburden and growth media, and contoured to promote runoff and minimize infiltration. The use of growth media in reclamation throughout the mine site is expected to encourage revegetation, which is important to long term slope stability and erosion control.

Potential direct impacts on bedrock during closure would range from low intensity in the pit where bedrock slopes/benches would remain as is, to medium intensity for the rest of the mine site, where shaping and covering of waste rock and exposed bedrock would occur. These effects would be permanent and localized (staying within the mine site footprint), and affect mostly common geologic resources.

*Summary of Mine Site Impacts – Bedrock Geology and Related Resources*

Potential direct impacts to bedrock at the mine site during construction, operations, and closure of Alternative 2 would range from low intensity (e.g., areas of minor grading during closure) to high intensity (ground disturbances and reshaping of landforms by blasting, excavation, and fill). These activities would result in the permanent alteration of about 505 Mt of ore and 2,765 Mt of waste rock from the 1,462 acre pit, and final elevation changes up to about 600 feet. All effects on bedrock would be local as they would be limited to areas within the mine footprint. While most bedrock impacted by the proposed project is considered common in context, the ore is a unique economic resource driving the purpose and need of the project.

## Transportation Facilities

### *Construction*

Disturbance of bedrock resources from construction activities along the transportation corridor could occur along the proposed mine access road route, at the new airstrip and permanent camp, and the Dutch Harbor fuel storage facility. No bedrock exposures occur in the community of Bethel or along the Kuskokwim River downstream of Kalskag, or at the Angyaruaq (Jungjuk) Port.

Impacts to bedrock from cut and fill activities could occur along ridge and side-slope segments of the proposed 30-mile long mine access road and 3-mile long airstrip spur road where shallow bedrock (bedrock less than six feet below the surface) is present. This occurs along roughly half of these road lengths, or a total of about 16 miles. The airstrip itself and permanent camp are also located on a ridge with potential shallow bedrock; these facilities would encompass approximately 23 and 10 acres, respectively. Indirect effects on bedrock from expansion of the Dutch Harbor fuel storage facility could encompass approximately 5 acres. Potential direct impacts to bedrock would occur at 12 out of 13 designated material sites along the mine access road where bedrock is present; these encompass a total of approximately 240 acres. Nine of the 12 sites would require blasting. Rock aggregate is a common resource in the region. The total volume of bedrock aggregate that would be removed and used in transportation facilities construction under Alternative 2 is about 2.8 million cubic yards (cy) (Recon 2011a).

Potential direct impacts on bedrock along transportation infrastructure would range from low intensity where only minor excavating or reshaping of the landscaping occurs, to high intensity where blasting, permanent reduction in material resources, or landform scars occur such as at borrow pits. Landforms that would be affected include primarily hills and ridges along the mine access road. These effects would be local in extent and affect a commonly available resource.

### *Operations and Maintenance*

Potential direct impacts on bedrock during operations could occur from utilization of bedrock aggregate to rehabilitate / refurbish road base and stream crossing passages along the mine access road, and stabilize foundation pads and the airstrip. During operations, three of the 13 material sites along the road would remain open for this purpose (SRK 2012f). Potential direct impacts to bedrock would likely occur across a small portion of the remaining material sites, and may require some additional blasting. Blasting and excavation effects would be permanent, localized, and of low to medium intensity in that additional extraction volumes of this commonly available resource would be small, and changes to landform character for the incremental amounts of aggregate used during operations may or may not be noticeable.

*Closure, Reclamation, and Monitoring*

During closure and post-closure, the main access road from the Angyaruaq (Jungjuk) Port to the mine site, airstrip, and permanent camp would remain to provide access for required long-term monitoring and water treatment at the Project Area (SRK 2012a). As such, three of the 13 material sites would remain open to provide aggregate for long-term road and airstrip maintenance. Potential direct impacts to bedrock from these activities would be the same as those described above for operations.

Ten of the 13 material sites would be reclaimed immediately after construction is completed (SRK 2012f) and the areas contoured to match existing landform to the extent practicable. The closure of the sites would reduce potential access to these common resources by other future users. Reclamation activities at bedrock material sites, which would be located on ridge tops and upper slopes, would involve minor grading, contouring, growth media placement, and revegetation; however, some bedrock may remain exposed in benched slopes in accordance with ADEC's Best Management Practices for Gravel/Rock Aggregate Extraction Projects (Shannon & Wilson 2012). Where graded and revegetated, the material sites are expected to remain stable and not result in adverse effects on other resources. Erosion control and inspection of material site reclamation are discussed in Section 3.2, Soils.

Potential direct impacts to bedrock material sites in closure from minor grading, contouring, and possible continued exposure to erosion (if slopes remain as is) would be permanent, of medium intensity (in that effects would generally be noticeable), cover local extents, and affect common geologic resources.

*Summary of Transportation Facilities Impacts – Bedrock Geology and Related Resources*

Potential direct impacts to bedrock along transportation facilities during construction, operations, and closure of Alternative 2 would range from low intensity (minor excavating or reshaping of the landforms) to high intensity (blasting, permanent reduction of material resources, landform scars). Impacts would primarily affect areas along the mine access road with shallow bedrock, (less than 2 meters below the surface) which applies to about 16 miles of road; an additional 400 acres at other facilities (airstrip, camp, material sites); and reduction of about 2.8 million cy of bedrock aggregate resources. These effects would be local in extent, as they would not extend outside the facility footprints, and affect a commonly available resource.

<u>Natural Gas Pipeline</u>

*Construction*

Disturbance of bedrock resources from construction activities along the 315-mile long pipeline would mostly occur in the western portion of the route in the Kuskokwim Hills where shallow bedrock is present. Twenty-seven of the 69 material sites along the pipeline contain bedrock, all but 4 of which are located in the western third of the pipeline route. The bedrock material sites cover a total of about 500 acres. Some of these may require blasting, the need for which would be determined in final design (SRK 2013b); however, rock similar to that expected in the Kuskokwim Hills was evaluated in the northern part of the mine access road and found to be rippable. The total volume of bedrock aggregate planned for use in pipeline and related infrastructure construction is roughly 2.8 million cy.

Intermittent shallow bedrock is expected within trenching depth west of the Kuskokwim River crossing from about MP 246 to the mine site (SRK 2013b). Sporadic shallow bedrock is also expected along a short (1-mile long) segment of the pipeline on the southeast side of Little Mount Susitna. Most of the bedrock encountered in boreholes in these areas is weathered and unlikely to require blasting during trenching. Bedrock beneath the right-of-way (ROW) in these areas would be subject to cut and fill construction in areas of steep cross-slopes. Shallow bedrock may also be impacted at other infrastructure sites in these areas, such as shoofly roads, camps, storage yards, and the Kuskokwim River airstrips. Bedrock impacts during HDD are described in Section 3.3, Geohazards and Seismic Conditions.

Potential direct impacts on bedrock along the pipeline would range from low intensity where only minor excavating or reshaping of the landforms occurs, to high intensity where blasting, permanent reduction in material resources, or landform scars occur such as at borrow pits. Landforms that would be affected along the pipeline route are described in Sections 3.1.2.3.1 and 3.1.2.3.3. Potential direct impacts from ground disturbance at material sites could include loss of slope stability and accelerated erosion (discussed in Section 3.2, Soils). These effects would be local in extent and affect a commonly available resource.

*Operations and Maintenance*

Potential direct impacts from Alternative 2 on pipeline entities during operations would likely involve little to no disturbance of bedrock at pipeline infrastructure sites such as access roads, airstrips, and material sites, as these are all planned to be reclaimed as soon as practicable following construction. Donlin Gold does not anticipate retention of material sites beyond the construction period. However, it is possible that selected sites may be reopened or retained for maintenance purposes. In this event, potential direct impacts would occur from bedrock aggregate utilization to rehabilitate/stabilize the ROW, stream crossings, and airstrips as needed. Potential direct impacts to bedrock in this case would occur across a small portion of any retained material sites and may require minor additional blasting. These impacts would be localized, permanent, and of low to medium intensity in that the extraction volumes of this commonly available resource would be small, and changes to landform character for the incremental amounts of material used during maintenance may or may not be noticeable.

*Closure, Reclamation, and Monitoring*

Potential direct impacts that could affect bedrock resources during closure would involve decommissioning of temporary infrastructure facilities that are located in shallow bedrock areas, such as access roads, airstrips, camps, material sites, storage yards, and ROW cuts in the Kuskokwim Hills portion of the pipeline route. During closure and reclamation, these facilities would be contoured to blend with original topography (SRK 2013b). Potential direct impacts to bedrock would be reduced by minor grading, contouring, topsoil replacement, and natural revegetation; however, some bedrock may remain exposed in benched slopes. Where graded and revegetated, the material sites are expected to remain stable and not result in adverse effects on other resources. Potential direct impacts on bedrock material sites and reclamation of pipeline infrastructure facilities in areas of shallow bedrock would be permanent, of medium intensity (in that effects would be noticeable), cover local extents, and affect common geologic resources.

*Summary of Natural Gas Pipeline Impacts – Bedrock Geology and Related Resources*

Potential direct impacts on bedrock along the pipeline during construction, operations, and closure of Alternative 2 would range from low intensity (minor excavating or reshaping of the landforms) to high intensity (blasting, permanent reduction of material resources, landform scars). Impacts would primarily occur in the western portion of the route where most shallow bedrock exists, and potentially affect about 70 miles of ROW and associated infrastructure (camps, storage yards, airstrip); bedrock material sites covering a total of 500 acres; and a total reduction of about 2.8 million cy of bedrock aggregate resources. These effects would be local in extent, as they would not extend outside the facility footprints, and affect a commonly available resource.

#### 3.1.3.2.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

<u>Mine Site</u>

*Construction*

As a result of Alternative 2, disturbance of surficial geology would occur across most areas of the mine site footprint. During pre-production at the pit and initial construction of the mine facilities, overburden would be excavated from about 80 acres of the pit, from the first and third lifts of the WRF, and about 2,400 acres of the TSF; the material would be placed in the North and South Overburden Stockpiles which would receive approximately 1.2 and 4.3 Mt across approximately 320 and 160 acres, respectively. Four gravel material sites would be utilized for construction purposes, encompassing an area of approximately 360 acres. These are planned along the east side of Crooked Creek, 3 of which would be co-located with (and predate) the placement of overburden and growth media stockpiles. Approximately 1.1 Mt of overburden would be utilized to construct foundation pads, 82,000 tons would be used to construct rock drains, and another 4.3 Mt would be used to construct roads (SRK 2012e).

Potential direct impacts from construction activities and ground disturbance would alter topography, and potentially expose unconsolidated materials to erosion. These potential impacts would be reduced by utilizing best management practices (BMPs) as described in Section 3.2.3.2.3 (Soils, Erosion, Mine Site) and Chapter 5 (Impact Avoidance, Minimization, and Mitigation). Potential direct impacts on surficial geology during construction would be permanent and of high intensity due to excavation, large scale redistribution of deposits, and reshaping of geomorphic landforms (hills and ridges). These effects would be localized in that they would be limited to the immediate mine site area. Gravel resources are not common in this area; however, demand for these resources is currently very low, and is likely to stay very low for the foreseeable future.

*Operations and Maintenance*

Potential direct impacts from Alternative 2 during operations would involve removal of overburden material across approximately 7,500 acres. Approximately 24.7 Mt of overburden would be generated from excavating the open pit and placed in the WRF. Roughly 800,000 tons of overburden would utilized for TSF dam construction during operations (SRK 2012e), and the North and South Overburden Stockpiles would receive approximately 5.0 and 6.1 Mt of overburden, respectively. Minor amounts of additional aggregate may be utilized during operations from the terrace gravel borrow pits. These ground disturbance activities could potentially expose unconsolidated material to erosion, unless mitigated by utilizing BMPs under a Multi-Sector General Permit (MSGP) for storm water discharges (discussed in Section 3.2, Soils).

Similar to the construction phase, potential direct impacts to surficial geology and gravel resources during operations would be localized, permanent, and of high intensity for this mostly common resource, due to excavation and redistribution of material and landforms.

*Closure, Reclamation, and Monitoring*

The Donlin Gold Project would utilize a "design for closure" concept at the mine site. The arrangement of major facilities such as the ultimate pit walls, WRF, mill, and TSF have been designed to limit overall ground disturbance beneath and between facilities, while allowing for the efficient extraction and processing of ore. Limited reclamation activities would be conducted during active operations, such as concurrent grading and contouring of inactive areas of the WRF, to minimize the volume of overburden stockpiles needing to be managed for erosion effects, minimize erosion and mass wasting effects at the WRF (Sections 3.2, Soils and 3.3, Geohazards and Seismic Conditions), and aid in early development of a vegetative cover.

Potential direct impacts on surficial deposits during closure and reclamation activities would involve utilization of approximately 424 Mt of waste rock (including 13,000 tons of overburden) to partially backfill the pit (SRK 2012e), and minor grading and contouring of the mine facilities and areas of the pit that allow human access. Haul roads around the pit would be smoothed of berms except those necessary for erosion control and safety (SRK 2012f).

Growth media used in site reclamation would include reuse of stockpiled surficial deposits. The total area of reclamation at the mine site involving reuse of surficial deposits is roughly 9,000 acres. At the completion of contouring of successive tiers in the WRF, a layer of unconsolidated material from the North and South Overburden Stockpiles would be spread over the surface and overlain with a layer of growth media (SRK 2012f). TSF closure would also include a cover of waste rock overlain by overburden material and growth media. The finished surface would be contoured to promote controlled runoff and reduce the potential for infiltration through the cap. While the physical and chemical characteristics of the existing surficial deposits could impede potential vegetative growth and/or be susceptible to erosion, these effects would be minimized through reclamation practices such as tilling prior to media placement, surface roughening, and soil amendments (SRK 2012f).

Potential direct impacts on surficial geology and gravel resources during closure would be permanent, of medium intensity (in that effects from grading and contouring would be noticeable), and cover a local extent, for this common geologic resource. Shaping and covering of surficial deposits with growth media would reduce impacts for soils and vegetation.

*Summary of Mine Site Impacts*

Potential direct impacts to surficial deposits and gravel resources at the mine site from construction, operations, and closure of Alternative 2 would range from medium intensity (grading and contouring in closure) to high intensity (large scale redistribution of deposits, reshaping of geomorphic landforms). These activities would result in the permanent change to roughly 40 Mt of overburden covering about 9,000 acres. Covering surficial deposits with growth media would result in mitigating impacts to soil and vegetation. All effects on surficial deposits and gravel resources would be local as they would be limited to areas within the mine footprint. Gravel resources in this area are not common, but potential demand from other possible users is very low.

Transportation Facilities

*Construction*

Disturbance of surficial geology from construction activities along the transportation corridor would occur along the proposed mine access road route, at the new airstrip, the Angyaruaq (Jungjuk) and Bethel port sites, and the Dutch Harbor fuel storage facility. Construction of the Bethel and Angyaruaq (Jungjuk) ports would impact surficial deposits across approximately 16 and 21 acres, respectively. Surficial deposits excavated for construction of the Angyaruaq (Jungjuk) barge berth would be placed in a stockpile at the north side of the port facility. Impacts to unconsolidated material during construction would occur during cut and fill and grading activities along the proposed 30-mile long, 2-lane, mine access road and 3-mile long spur road off of the mine access road to the new airstrip would impact roughly 300 acres. Surface disturbances at the airstrip would encompass approximately 100 acres. Indirect effects on surficial deposits from the expansion of the Dutch Harbor fuel storage facility could encompass approximately 5 acres.

Potential direct impacts to gravel resources would also occur at one of the 13 material sites along the mine access road. Material Site MS10 located on an alluvial plain in the Getmuna Flats area encompasses an area of approximately 200 acres. Gravel resources are somewhat limited in this region of Alaska; however current demand is also low. The volume of material that would be removed from this site and used in transportation infrastructure construction under Alternative 2 is roughly 1.5 million cubic yards (cy) (Recon 2011a).

Impacts on surficial geology and gravel resources as a result of Alternative 2 would range from low intensity where minor excavating or grading occurs (e.g., at Bethel Port, a previously disturbed site), to medium intensity where road cuts and fills are noticeable, and higher intensity impacts at the MS10 borrow site where large scale resource reduction would occur. These effects would be long-term (extending through the life of the project) to permanent, cover local extents, and affect resources considered common to important in context.

*Operations and Maintenance*

Potential direct impacts during operations would likely involve minimal disturbance to surficial geology and gravel aggregate along the transportation corridor. Impacts could occur from the use of gravel aggregate to rehabilitate / refurbish road base and stream crossings along the mine access road, and to potentially stabilize foundation pads, ports, and the airstrip, if MS10 remains open for this purpose during the operations period. In this event, impacts would likely occur across a small portion of this borrow site and the infrastructure requiring maintenance, and would include minor excavation, fill, and grading. These impacts would be long-term to permanent, of low to medium intensity (in that the incremental resource reduction, landform changes, and repairs may or may not be noticeable), and cover local extents, for this common to important geologic resource.

*Closure, Reclamation, and Monitoring*

During closure and post-closure, the mine access road, airstrip, and permanent camp would remain to provide access for required long-term monitoring of the project site. It is possible that the Getmuna Creek material site (MS10) would remain open to provide gravel aggregate for long-term road maintenance. Direct effects from these activities would be the same as described above for operations. Detailed plans for closure of MS10 have not yet been specified, but would likely include minor grading and contouring and/or possible creation of fish and wildlife habitat using ponds or stream connections in accordance with ADEC and ADF&G guidance (Chapter 5, Impact Avoidance, Minimization, and Mitigation). Closure may also preclude access to these potentially important aggregate resources by other future users, although the current potential for other uses is low.

The Angyaruaq (Jungjuk) Port would be decommissioned and reclaimed during closure. Potential direct impacts to surficial deposits would involve minor grading and contouring to blend with original topography (SRK 2012f). Potential indirect effects from exposed surficial deposits causing erosion or impeding vegetative growth would be minimized through growth media placement, tilling and soil amendments.

Potential direct impacts on surficial geology and aggregate resources during closure from minor grading and contouring would be permanent, of medium intensity (effects would be noticeable), cover local extents at the Angyaruaq (Jungjuk) Port and MS10, and would involve common to important geologic resources.

*Summary of Transportation Facilities Impacts*

Potential direct impacts on surficial geology and gravel resources along the transportation corridor during construction, operations, and closure of Alternative 2 would range from low intensity (minor excavating or grading) to high intensity at the MS10 borrow site where large scale resource reduction would occur. Impacts would involve ground disturbance and landform alterations across a total of about 700 acres and reduction of about 1.5 million cy of gravel resources. These effects would be long-term (extending through the life of the project) to permanent and cover local extents. These resources are considered common to important in context, as the availability of gravel aggregate is somewhat limited in this region of Alaska, although the current potential for other uses of the resource is limited.

<u>Natural Gas Pipeline</u>

*Construction*

Disturbance of surficial geology and gravel resources from excavation and grading activities during construction would occur at a number of facilities and locations along the pipeline. Except at fault crossings and stream crossings, construction of the pipeline would require excavation of surficial deposits in the 1.5- to 2.5-foot wide trench zone throughout the length of the pipeline (about 50 to 90 acres). The total ROW acreage that would be cleared for construction is roughly 5,750 acres (150 feet wide), with up to an additional 5,750 acres available (up to 300 feet wide) for additional temporary space that may be needed in areas of challenging ground conditions (SRK 2013b). There would be little to no impact on surficial deposits within the ROW in areas of wetland construction using mats or winter construction in flat terrain. Much of the ROW and access roads, however, are located in areas with cross-slopes that would require cut and fill construction. These conditions occur throughout most of the Alaska Range and Kuskokwim Hills portions of the route, are common in Cook Inlet Basin and upper Skwentna Valley, and occur intermittently along the north front of the Alaska Range. The total length of ROW requiring cut and fill construction and increased grading due to cross-slopes (generally greater than 6 percent) would be about 262 miles under Alternative 2. Conservatively assuming the maximum ROW width is needed for all of these segments, the total area of impacts to surficial deposits would be roughly 10,500 acres. The total length of shoofly roads potentially requiring cut and fill construction is about 80 miles and would cover about 560 acres.

Six of the 9 new airstrips (about 330 acres) would also require some cut and fill construction. Specific siting was conducted to reduce the amount required for runway construction (SRK 2013b). Impacts to surficial geology during construction of the remaining airstrips and at storage yards, camps, stream crossings, and the compressor station would be mostly limited to minor disturbances during grading, leveling, and drilling activities across a total of roughly 500 acres.

Impacts to gravel resources would occur at 45 material sites encompassing roughly 550 acres. Direct effects on surficial deposits at material sites include exposure to erosion (Section 3.2, Soils); and excavation, removal, and redistribution of material. The total estimated volume of aggregate usage from gravel material sites under Alternative 2 is roughly 3.1 million cy (SRK 2013b).

Potential direct impacts on surficial geology as a result of Alternative 2 would range from low intensity where only minor grading occurs (e.g., at camps and storage yards), to medium intensity where ROW, road, and airstrip cuts and fills are noticeable, and high intensity at gravel pits where landform scars are obvious and large scale resource reduction occurs. These effects would range from temporary (extending through the construction phase only) to permanent (for some landform alterations), cover local extents (effects within the Project Area), and affect resources considered common to important in context. Gravel resources are widely available in the glaciated deposits of Cook Inlet basin, Skwentna Valley, and braided rivers draining the Alaska Range, and less so in the Kuskokwim Hills. However, there is little demand for gravel resources outside of Cook Inlet basin.

### *Operations and Maintenance*

Potential direct impacts during pipeline operations and maintenance would likely involve minimal disturbance to surficial geology and gravel aggregate at pipeline infrastructure sites such as access roads, airstrips, and material sites, as these are all planned to be reclaimed as soon as practicable following construction. Donlin Gold does not anticipate retention of material sites beyond the construction period. However, it is possible that selected sites may be reopened or retained for maintenance purposes. In this event, potential direct impacts could occur from the use of aggregate to rehabilitate / refurbish the ROW and stream crossings along the pipeline as needed. Potential direct impacts in this case would likely occur across a small portion of any such material sites. These impacts would be localized, permanent, and of low to medium intensity, in that the additional extraction volumes of this common to important resource would be small, and changes to landform character for the incremental amounts of material used for maintenance may or may not be noticeable.

*Closure, Reclamation, and Monitoring*

Immediately following pipeline installation, ROW cuts in surficial deposits would be graded to match original contours; workpad fills would remain in place (SRK 2013b). At the end of the construction period, temporary infrastructure such as access roads, airstrips, camps, material sites, and storage yards would be decommissioned as soon as practicable. During closure and reclamation activities, these areas would undergo minor grading and contouring to blend with original topography, provide for adequate drainage, and prevent erosion (Section 3.2, Soils), resulting in mitigating impacts to soils and vegetation. Impacts at gravel material sites would involve more extensive grading and contouring. Closure actions at material sites may preclude access to these aggregate resources by future users.

The pipeline, compressor station, and any maintenance sites that may have been used during operations, would be closed at the end of the project. There would be no disturbance of the ROW during closure activities, as the pipeline would remain buried. Minor excavation and grading would occur at fault crossings, maintenance sites, and compressor station site following infrastructure removal.

Potential direct impacts on surficial geology and aggregate resources would be permanent, of medium intensity (in that grading and contouring effects would be noticeable), cover local extents, and affect a common to important geologic resource.

*Summary of Natural Gas Pipeline Impacts*

Potential direct impacts on surficial geology and gravel resources along the pipeline during construction, operations, and closure of Alternative 2 would range from low intensity (e.g., minor grading at camps) to high intensity (landform scars and resource reduction at gravel pits), although reclamation activities would result in mitigating impacts to soils and vegetation. Impacts would occur across the majority of the route, potentially affecting about 262 miles of ROW and 80 miles of shoofly roads where cross-slopes may require cut and fill construction; roughly 2,100 acres of associated infrastructure; and would result in a total reduction of about 3.1 million cy of gravel resources. These effects would range from temporary (extending through the construction phase only) to permanent (for resource use and landform alterations), and would be local in extent, as they would not extend outside the Project Area. Impacts would affect resources considered common to important in context, as gravel material is widely available in the eastern and central parts of the route, and less so in the Kuskokwim Hills.

### 3.1.3.2.3 PALEONTOLOGICAL RESOURCES

<u>Mine Site</u>

*Construction*

Disturbance of paleontological resources could occur across the same areas described above for bedrock effects at the mine site (Section 3.1.3.2.1), as paleontological resources are associated with bedrock units (formations, members, beds) that contain them. Impacts to paleontological resources could occur through the destruction of fossil-bearing bedrock (by blasting, excavation, and grading) that reduces the availability of fossils potentially valuable for research and exposes them to erosion (Section 3.2, Soils). Mine blasting and excavation could also have the beneficial effect of exposing new bedrock surfaces and increase the availability of fossils. However, new outcrops may be difficult to access, and the context and age of loose samples may be lost owing to mixing of different stratigraphic horizons. Unauthorized collecting would be limited at this controlled access site.

Donlin Gold has conducted studies (Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013; Reuther et al. 2014) to assess the fossil potential of the mine region using a PFYC system developed by the U.S. Bureau of Land Management (BLM) (Table 3.1-1), which provides guidance for predicting, assessing, and mitigating paleontological resources, and is useful in understanding the importance of these resources in context. The PFYC system serves as a process for determining whether vertebrate fossils, or noteworthy occurrences of other fossils, are known or likely to occur in an area (BLM 1998).

Figure 3.1-5 depicts PFYC values for the mine site region. If fossils are present at the mine site, they are only likely to be present in Kuskokwim Group sedimentary rocks that have not been altered by hydrothermal processes (i.e., they are very unlikely to be present in ore). Non-marine strata within the Kuskokwim Group are known to contain abundant plant fossils, which are associated with a high potential for dinosaur tracks and skeletal remains based on similarities to other areas of Alaska (see Section 3.1.2.1.4). Their potential presence at the mine site is unknown, and while no obvious macrofossils have been found to date in nearby outcrops, exposures of non-marine Cretaceous rocks are limited in the area (Reuther et al. 2014). Part of the mine site is rated PFYC Class 2 (most of the open pit), indicating low fossil potential or invertebrate fossils present from abundant species; and part of the mine site is rated Class 3b (east and south sides of pit, and areas beneath the WRF and TSF), meaning these rocks have unknown fossil potential and that further reconnaissance and research may be necessary to determine potential impacts.

Quaternary vertebrate fossils have also been reported in overlying sediments in the area (Reuther et al. 2014).

Thus, paleontological resources at the mine site are considered to range from common to important in context, depending on whether dinosaur fossils are present. Potential direct impacts on these resources as a result of Alternative 2 would be permanent, of medium to high intensity (due to blasting and grading), and local in extent, affecting roughly 30 Mt of waste rock covering 80 acres in the pit area, and 480 acres in the process facility area which may require grading of a bedrock ridge (Section 3.1.3.2.1). Potential beneficial effects from exposure of new fossils would be temporary during construction due to planned pit widening and earthworks in operations. New outcrops could be difficult to access, and the stratigraphic horizon from which liberated fossils in loose rock come from may be obscured by material movement during construction.

*Operations and Maintenance*

During operations, approximately 2,765 Mt of potential paleontological resource-containing bedrock covering about 1,462 acres would be blasted and excavated from the pit (SRK 2012e). Most of this rock would be permanently buried in the WRF (Section 3.1.3.2.1). As with the construction period, these activities could destroy or cover potentially important paleontological resources, particularly in the east and south sides of the pit, expose them to erosion, and reduce the availability of fossils for research. Bedrock beneath the WRF and TSF that would be covered during operations and inaccessible for future research encompasses about 5,400 acres.

Potential beneficial effects from exposure of fossils in new outcrops in the pit would be long-term (lasting for the life of the mine), with controlled access preventing unauthorized collection. There is a very low likelihood that these exposures, and the availability of these fossils for possible study, would exist without the mine. While pit wall stability would generally be maintained during the life of the mine, the exposures would likely experience some minor sloughing and erosion during operations, which may displace the fossils from their original stratigraphic location. In general, fossils in float lose some information about age and environment as compared to in situ fossils. The potential beneficial effects of new outcrops are dependent on adoption of additional mitigation measures (described in Chapter 5, Impact Avoidance, Minimization, and Mitigation). Thus, direct impacts during operations would be permanent, mostly of high intensity, and cover a local extent for this common to important resource.

*Closure, Reclamation, and Monitoring*

During closure and reclamation activities, roughly 424 Mt of potential fossil-containing waste rock would be used to backfill portions of the pit (SRK 2012e), which would eventually become permanently covered by water. Grading and contouring of mine facilities during closure would permanently cover some paleontological resources. Minor sloughing and raveling of the pit walls is expected to occur during post-closure, conditions which would not be maintained or repaired, and would cover potential fossil-bearing outcrops. Formation of a pit lake would make future access for research unsafe. Thus, there would be no beneficial effects to potential fossil-bearing rock exposures during this phase of the project. Direct impacts on paleontological resources during closure would be permanent, of medium intensity (from noticeable grading, erosion, and sloughing), and cover a local extent for this common to important resource.

*Summary of Mine Site Impacts*

Potential direct impacts to paleontological resources at the mine site during construction, operations, and closure of Alternative 2 would to range from medium intensity (noticeable grading and sloughing of rock exposures) to high intensity (blasting and resource removal). These activities would result in the permanent alteration of a total of about 2,765 Mt of potentially fossil-bearing rock (waste rock) covering about 1,462 acres in the pit area, and permanent burial of potential fossil-bearing rock in other areas of the site covering about 6,000 acres. Potential beneficial effects from exposure of new fossils in pit wall outcrops would be dependent on adoption of additional mitigation measures (described in Chapter 5, Impact Avoidance, Minimization, and Mitigation). All effects would be local as they would be limited to areas within the mine footprint. While most rock impacted by the proposed mine is expected to be either non-fossiliferous or rated PFYC Class 2 and would therefore be considered common in context, non-marine strata in the east and south sides of the pit (rated Class 3b) have unknown fossil potential and further evaluation of pit walls would be necessary to determine their importance. A Cultural Resources Management Plan (CRMP) is being developed as part of the proposed project that will include mitigation for potential paleontological resources as well as cultural resources. The CRMP will identify measures that would help to minimize effects on potential fossils encountered.

## Transportation Facilities

### *Construction*

Disturbance of paleontological resources from construction of the various transportation facilities could occur along the proposed mine access road route, at the new airstrip and permanent camp, along the Kuskokwim River corridor, and at the Dutch Harbor fuel storage facility. Impacts to these resources would occur through destruction of bedrock by excavation and blasting at material sites, road cuts, and infrastructure facilities; and erosion of cut slopes and river bluffs. Surface disturbances may also have the beneficial effect of exposing additional outcrops for study or public education.

Fossils potentially present along the mine access road would likely be contained in sedimentary Kuskokwim Group rocks. The PFYC values and high potential for dinosaur fossils in these rocks are considered the same as those described above for the mine site. Kuskokwim Group rocks rated Class 2 and 3b have been mapped along a total of about 7 miles of the northern portion of the mine and airport access roads, at 3 materials sites in this area covering about 33 acres, and at the airstrip itself which extends across 23 acres (Jacobus and Druckenmiller 2013). The central and southern portions of the mine access road are mostly underlain by intrusive and volcanic igneous rocks with no fossil potential. Young (Holocene age) surficial deposits at the Angyaruaq (Jungjuk) Port are considered to have low potential for paleontological resources (Reuther et al. 2014). No bedrock or Pleistocene exposures are found in the community of Bethel.

The potential for significant Pleistocene vertebrate fossils (e.g. mammoth, bison) is considered high along the Kuskokwim River from about 8 miles downstream of Jungjuk to the Napaimute vicinity (Reuther et al. 2014), a total of about 25 miles. Potential effects from barge-induced erosion in exposing these fossils in river bluffs are expected to be of low intensity (BGC 2007a), particularly when compared to natural erosion by river flooding and ice during breakup (Section 3.5, Surface Water Hydrology). Two critical sections of the river where barge tows may need to relay during low water conditions (Holokuk and Oskawalik North) are located in this area. Intermittent increased shoreline activities at these locations could contribute to localized bank/bluff erosion and increased access for unauthorized fossil collection. Depending on the presence or absence of vertebrate fossils at these specific locations, effects could range from low to high intensity and could affect common to important paleontological resources. The use of BMPs to prevent soil erosion (Section 3.2, Soils), however, is expected to minimize new exposures of fossils at these locations.

The Dutch Harbor fuel storage facility would likely be located in an area underlain by volcanic rock with little to no fossil potential. While vertebrate and invertebrate fossils (marine mammals, bivalves) have been documented in sedimentary sections of the Unalaska Formation, the stratigraphic trend of these rocks suggest that units underlying the port areas of Dutch Harbor are composed primarily of the non-fossiliferous upper volcanic sequence of this formation (Lankford and Hill 1979).

Direct impacts on paleontological resources during construction of the various transportation infrastructure sites would be permanent, would range from low intensity (minor grading, erosion) to high intensity (blasting, unauthorized collection), and would cover local extents. Paleontological resources in these areas range from common to important in context.

### *Operations and Maintenance*

Potential direct impacts from Alternative 2 during operations would likely involve minimal additional disturbance to paleontological resources at the three material sites that remain open for maintenance purposes along the proposed mine access road route (Section 3.1.3.2.2). While the three sites have not been selected yet, it is likely that one of the three could be located in Kuskokwim Group rocks in the northern portion of the road. Direct impacts from excavation, blasting, and exposure of these rocks to erosion would be permanent, of low to high intensity (small volumes, but some potential destruction of resources), and cover local extents for this common to potentially important resource. Potential direct impacts to Pleistocene vertebrate fossils at relay points along the Kuskokwim River corridor upstream of Napaimute would be the same as described above for construction.

### *Closure, Reclamation, and Monitoring*

Potential direct impacts to paleontological resources along the mine access road and remaining material sites during closure and post-closure would be the same as those described above for operations, as these facilities would remain open to support long-term monitoring and water treatment. The likelihood of incremental effects on Pleistocene fossils at relay points along the Kuskokwim River corridor is low during closure, as the minor barging required to support closure and post-closure activities would likely be timed to avoid low water periods and the need for relays at critical sections.

### *Summary of Transportation Facilities Impacts*

Potential direct impacts on paleontological resources along the transportation corridor during construction, operations, and closure of Alternative 2 would range from low intensity (e.g., minor grading at airstrip, erosion at relay points) to high intensity (e.g., blasting at material sites, unauthorized collection at relay points). Potential beneficial effects from exposure of new fossils in material site outcrops would be dependent on adoption of additional mitigation measures (described in Chapter 5, Impact Avoidance, Minimization, and Mitigation). These effects would range from long-term (extending through the life of the project) to permanent. Impacts would be localized within the following specific locations having fossil potential: road cuts along 7 miles of the northern part of the mine/airstrip access roads, at the airstrip and 3 material sites (about 60 acres total), and at 2 low-water relay points upstream of Napaimute. Paleontological resources at these locations range from common in context (formations with low fossil potential) to important, where the potential is high for dinosaur fossils in Kuskokwim Group rocks or vertebrate fossils in Pleistocene deposits. A CRMP is being developed as part of the proposed project would minimize effects on potential fossils encountered.

## <u>Natural Gas Pipeline</u>

### *Construction*

Disturbance of pre-Quaternary paleontological resources from construction activities along the pipeline could occur primarily at material sites, ROW cross-slope cuts, and shoofly road cuts in the western portion of the pipeline corridor. The fossil potential of the sedimentary Kuskokwim Group rocks in this area is described above under Mine Site and shown on Figure 3.1-5. PFYC values of 2 and 3b for these rocks suggest they range from common to important in context, depending on the potential presence of dinosaur fossils. Shallow Kuskokwim Group bedrock underlies about 70 miles of pipeline ROW, 40 miles of associated shoofly roads, and about 460 acres of material sites. Bedrock material sites near the southeastern end of the pipeline corridor (Little Mount Susitna area) target igneous rocks with no fossil potential. One bedrock material site in the Alaska Range near MP 130, covering about 27 acres, would be located in the southeast McGrath Quadrangle where fossil localities have been assigned PFYC values of 2 and 3a (Table 3.1-1), indicating low to moderate yield potential or the presence of abundant invertebrate specimens.

No fossils have been recorded in the widely distributed Quaternary deposits in the Alaska Range foothills and Cook Inlet areas of the pipeline route, partly because they are poorly documented, but it is possible these deposits contain Pleistocene vertebrate remains of scientific interest (Druckenmiller et al. 2013). No PFYC values have been assigned to the Quaternary deposits. The extent of Quaternary deposits that could be disturbed during pipeline construction is similar to estimates provided in Section 3.1.3.2.2 for surficial deposits: for example, cross-slope cuts could occur along roughly 262 miles of the pipeline ROW and 80 miles of shoofly roads, and gravel material sites would cover about 550 acres. Based on fossil occurrences in other areas of Alaska (e.g., BLM 2002a; Porter 1988; Reuther et al. 2014), Pleistocene vertebrate fossils are more likely to be preserved in loess, glaciofluvial, and fluvial deposits (such as the alluvial terrace deposits targeted by some of the gravel material sites on the north front of the Alaska Range), and less likely to be found in coarse glacial deposits such as the morainal deposits of upper Skwentna Valley.

Potential direct impacts to these resources during construction activities could occur through excavation of ROW and road cuts; possible blasting at material sites; trench excavation; grading at infrastructure sites; and exposure of fossil-bearing formations to erosion. These impacts would be permanent, of low to high intensity, cover local extents, and affect common to potentially important resources. Beneficial effects could also result from exposing new fossil-bearing outcrops for study.

As part of the proposed project, Donlin Gold would develop a Paleontological and Cultural Resources Protection Plan that would include measures for protection of unanticipated discoveries of paleontological resources and sites, such as notification of significant discoveries to State Pipeline Coordinator’s Office (SPCO) or other appropriate authorities (SRK 2013b). Additional plan details have not been specified to date.

*Operations and Maintenance*

Direct impacts during operations would likely involve minimal disturbance to paleontological resources, as all pipeline infrastructure is planned to be reclaimed as soon as practicable following construction. In the event that selected material sites are reopened or retained for maintenance purposes, direct impacts from additional ground disturbance would be the same as described above for construction, but on a much smaller, more localized scale.

*Closure, Reclamation, and Monitoring*

Direct impacts to paleontological resources during closure and reclamation activities would involve grading and contouring of potential fossil-bearing exposures at material sites, and ROW and road cuts. These activities would protect paleontological resources from further ground disturbances, but also preclude access for further study. These effects would be permanent, of low to medium intensity, and cover local extents for this common to important resource.

*Summary of Natural Gas Pipeline Impacts*

Direct impacts on paleontological resources along the pipeline during construction, operations, and closure of Alternative 2 could range from low intensity (e.g., grading at infrastructure sites) to high intensity (e.g. ROW and road cut excavations, blasting at material sites), depending on the actual presence of fossils. Beneficial effects could also result from exposing new fossil-bearing outcrops for study. These effects would range from temporary (exposures open during construction phase only) to permanent (e.g., resources removed from material sites). Impacts would be localized within the Project Area, and at locations having fossil potential: pre-Quaternary and Quaternary deposits along roughly 262 miles of the pipeline ROW, 80 miles of shoofly roads, and material sites covering about 1,000 acres. Paleontological resources along the pipeline range from common (formations with no or low fossil potential) to important, e.g., where the potential is high for dinosaur fossils in Kuskokwim Group rocks. A CRMP is being developed as part of the proposed project which would minimize effects on potential fossils encountered.

#### 3.1.3.2.4 CLIMATE CHANGE

Predicted overall increases in temperatures and precipitation and changes in the patterns of their distribution have the potential to influence the projected effects of the Donlin Gold Project on surficial geology, aggregate resources, and paleontological resources. These effects are generally associated with changes in permafrost and increased risk of erosion as discussed in Sections 3.26.4.2.3 and 3.26.4.2.2.

#### 3.1.3.2.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 2

Direct impacts to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources at the mine site would range from low intensity (e.g., areas of minor grading of bedrock during closure) to high intensity (e.g., blasting and resource removal, major landform changes, and widespread aggregate resource utilization). These activities would result in the permanent alteration of resources. All effects on geologic resources would be local in extent, as they would be limited to areas within the mine footprint. While most bedrock impacted by the proposed project is considered common in context, the ore is a unique economic resource that is driving the purpose and need of the project. Gravel resources in the area of the mine site are considered common to important in context, but potential demand from other users is very low. There is also Cretaceous non-marine strata located in the east and south sides of the pit that have unknown fossil potential, but could be important in context if dinosaur fossils are present. Reshaping and covering surficial deposits with growth media would result in mitigating related impacts to soil and vegetation. Potential beneficial effects from exposure of new fossils in pit wall outcrops would be dependent on adoption of additional mitigation measures as well. Overall impacts at the mine site to these geologic resources are considered minor to moderate.

At the transportation facilities, direct impacts to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources would range from low intensity (e.g., minor excavating, grading at airstrip) to high intensity (e.g., blasting, permanent reduction of material resources). High intensity impacts would be experienced specifically at the MS10 borrow site, where large-scale gravel resource reduction would occur. These effects would be considered long-term to permanent in duration. Most impacts would primarily affect localized areas within the transportation facilities footprints. These geologic resources are considered common to important in context. The availability of gravel aggregate is somewhat limited in this region of Alaska, and the transportation facilities intersect with areas with high potential for dinosaur or vertebrate fossils. Overall impacts associated with the transportation facilities for geologic resources are considered minor to moderate.

For the natural gas pipeline, the summary impact to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources would be minor to moderate as well. The intensity of impacts would range from low (e.g., minor excavating) to high (e.g., blasting, permanent reduction of materials, landform scars). Beneficial effects could also result from exposing new fossil-bearing outcrops for study. Impacts would range from temporary (e.g., paleontological resource exposure during the construction phase only) to permanent (for resource use and landform alterations). All impacts would be considered local in extent, as they would not extend beyond the Project Area. Resources considered common to important (e.g., areas with high potential or dinosaur or vertebrate fossils) in context would be impacted. Gravel material is widely available in the eastern and central parts of the pipeline route, but less so in the Kuskokwim Hills.

Table 3.1-4 summarizes the impact levels of Alternative 2 by project component and subresource.

**Table 3.1-4: Alternative 2 Impact Levels by Project Component**

| Impacts | Impact Level | | | | |
|---|---|---|---|---|---|
| | **Magnitude or Intensity** | **Duration** | **Geographic Extent** | **Context** | **Summary Impact Rating[1]** |
| **Mine Site** | | | | | |
| Bedrock Geology and Related Resources | Low to High | Permanent | Local | Common or Unique (ore) | Minor to Moderate |
| Surficial Geology and Gravel Resources | Medium to High | Permanent | Local | Common | Minor to Moderate |
| Paleontological Resources | Medium to High | Permanent | Local | Common to Important | Minor to Moderate |
| **Transportation Facilities** | | | | | |
| Bedrock Geology and Related Resources | Low to High | Permanent | Local | Common | Minor to Moderate |
| Surficial Geology and Gravel Resources | Low to High | Long-term to Permanent | Local | Common to Important | Minor to Moderate |
| Paleontological Resources | Low to High | Long-term to Permanent | Local | Common to Important | Minor to Moderate |

**Table 3.1-4: Alternative 2 Impact Levels by Project Component**

| Impacts | Impact Level | | | | |
|---|---|---|---|---|---|
| | Magnitude or Intensity | Duration | Geographic Extent | Context | Summary Impact Rating[1] |
| **Pipeline** | | | | | |
| Bedrock Geology and Related Resources | Low to High | Permanent | Local | Common | Minor to Moderate |
| Surficial Geology and Gravel Resources | Low to High | Temporary to Permanent | Local | Common to Important | Minor to Moderate |
| Paleontological Resources | Low to High | Temporary to Permanent | Local | Common to Important | Minor to Moderate |

**Notes:**

1 The summary impact rating accounts for impact reducing design features proposed by Donlin Gold and Standard Permit Conditions and BMPs that would be required. It does not account for additional mitigation measures the Corps is considering.

As discussed above, these effects determinations take into account impact-reducing design features (Table 5.2-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) proposed by Donlin Gold and also the Standard Permit Conditions and BMPs (Section 5.3, Chapter 5, Impact Avoidance, Minimization, and Mitigation) that would be implemented. Several examples of these are presented below.

Design features most important for reducing impacts to geology include:

- Areas of disturbed bedrock and surficial deposits along the ROW, roads, and material sites would be contoured to match existing landforms as feasible, ripped to mitigate compaction effects, covered with growth media as needed and revegetated, and would support the overall drainage of the site, the long-term geotechnical stability, and post-mining land use;
- At the completion of contouring of the WRF and TSF, a layer of unconsolidated material from the North and South overburden stockpiles would be spread over the surface and overlain with an additional layer of growth media (topsoil and overburden). This material will be tested to ensure it is non-PAG. The WRF would be designed to maximize concurrent reclamation, minimize the effects of PAG materials, minimize infiltration and erosion, and promote controlled surface runoff and revegetation; and
- The pipeline right-of-way would be reclaimed immediately following construction (in the same or the next season) to minimize erosion effects on exposed bedrock and surficial deposit cuts.

Standard Permit Conditions and BMPs most important for reducing impacts to geology include:

- Implementation of Stormwater Pollution Prevention Plans (SWPPPs) and/or Erosion and Sediment Control Plans; and
- Preparation and implementation of a Stabilization, Rehabilitation, and Reclamation Plan.

#### 3.1.3.2.6 ADDITIONAL MITIGATION AND MONITORING FOR ALTERNATIVE 2

The Corps is considering additional mitigation (Table 5.5-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) to reduce the effects presented above. These additional mitigation measures include:

- Depending on permitter/stakeholder/landowner interest, consideration should be given to leaving accessible borrow sites open beyond project closure. This may mitigate area wide geologic impacts, through use of existing sites, rather than opening of new sites for borrow materials.
- There is a potential for scientifically significant pre-Quaternary paleontological resources (dinosaur fossils) to be found during ground disturbing operations. Donlin Gold has submitted an initial draft of a Cultural Resources Management Plan which includes management of cultural and paleontological resources on BLM, State, and private land. The plan would prescribe an effective process for managing potential effects on these resources, and ensure that agreed-upon and approved procedures are established. At a minimum, the plan would include:
    - Training of workers regarding cultural resource issues and responsibilities;
    - Measures to avoid or minimize impacts to cultural resources (e.g., flagging, monitoring);
    - Standard protocols for any known cultural resources that may be exposed during project construction, operations, and reclamation;
    - Prescribed actions to be taken in the event that unanticipated cultural resources are discovered, or known resources are impacted in an unanticipated manner; and
    - Protocols for treatment of any discovered human remains.

The plan should also include procedures for notification, documentation, sampling, and curation in the event that significant fossils are found.

The Corps is not considering additional monitoring (Table 5.7-1, Chapter 5, Impact Avoidance, Minimization, and Mitigation) to reduce the effects presented above.

If these mitigation measures were adopted and required, the summary impact rating for the mine site, transportation facilities, and pipeline would be reduced, but would remain minor to moderate.

### 3.1.3.3 ALTERNATIVE 3A – REDUCED DIESEL BARGING: LNG-POWERED HAUL TRUCKS

#### 3.1.3.3.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Effects on bedrock and related resources under Alternative 3A would be the same as those described for Alternative 2 for the mine site and natural gas pipeline project components. While there would be slightly less effects on shallow bedrock at transportation facilities due to the elimination of Dutch Harbor fuel storage expansion under this alternative, the reduction would be small (about 5 acres) compared to overall bedrock impacts for transportation facilities (about 400 acres and 16 miles of road).

### 3.1.3.3.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

#### Mine Site

Effects on surficial geology and gravel resources under Alternative 3A would be the same as those described for Alternative 2 for the mine site. Some diesel fuel storage facility space would be decreased, and space for the LNG production and storage facilities would be required, thus likely resulting in a neutral impact to surficial geology. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use between the two alternatives.

#### Transportation Facilities

Effects on surficial geology under Alternative 3A would be the same as Alternative 2, except for a reduction in utilization of surficial deposits at the Dutch Harbor and Bethel ports. Because these ports would not require as much expansion (if any) under Alternative 3A, total disturbances of surficial deposits would be reduced by about 10 to 20 acres, as would the need for gravel aggregate fill for these facilities. However, because this is a small area compared to the total area of impacts for transportation facilities (about 700 acres), the range of effects would be the same as Alternative 2 (e.g., low to high intensity, for minor grading to large scale resource reduction at material sites) (Section 3.1.3.2.2).

#### Natural Gas Pipeline

Impacts to surficial geology and gravel resources associated with the construction, operations, and closure of the natural gas pipeline would be the same as discussed under Alternative 2.

### 3.1.3.3.3 PALEONTOLOGICAL RESOURCES

#### Mine Site

Effects on paleontological resources under Alternative 3A would be the same as those described for Alternative 2 for the mine site. There would be no difference in the types of impacts and amount of ground disturbance for this component.

#### Transportation Facilities

The reduction in barging associated with Alternative 3A would reduce potential impacts on Quaternary fossils along the Kuskokwim River bank. Activities at relay points along the river would be rare under this alternative, as reduction of barge traffic by about one-third would nearly eliminate the need for barge travel during low water conditions. Thus, there would be a low likelihood of shoreline access to potential fossils at relay points, and the potential for impacts (if any) would occur very infrequently. However, the reduction of impacts along the river would not change the range of effects on paleontological resources for other transportation facilities, which range from low to high intensity (e.g., for minor grading at airport, to blasting at bedrock material sites).

Natural Gas Pipeline

Effects to paleontological resources under Alternative 3A would be the same as discussed under Alternative 2.

#### 3.1.3.3.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 3A

Effects on bedrock, mineral / rock aggregate resources, surficial deposits, gravel resources, and paleontological resources under Alternative 3A at the mine site and the natural gas pipeline would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. Some diesel fuel storage facility space would be decreased, and space for the LNG production and storage facilities would be required, thus likely resulting in a neutral impact to surficial deposits. There would be no difference in the amount of ground disturbance affecting surficial deposits, paleontological resources, or the amount of gravel aggregate use between the two alternatives at the mine site. Like Alternative 2, overall impacts to the mine site and natural gas pipeline are considered minor to moderate.

Effects associated with the transportation facilities under Alternative 3A would be similar to those described for Alternative 2. Even though there would be a reduction in effects to shallow bedrock and the utilization of surficial deposits because the Dutch Harbor and Bethel ports would not require as much expansion under Alternative 3A, the reduction would be small compared to other impacts to transportation facilities discussed under Alternative 2, and therefore would not change the overall impact ratings for the transportation facilities of minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required for Alternative 3A, the summary impact rating would remain similar to Alternative 2; minor to moderate.

### 3.1.3.4 ALTERNATIVE 3B – REDUCED DIESEL BARGING: DIESEL PIPELINE

#### 3.1.3.4.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the mine site under Alternative 3B would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use.

Transportation Facilities

Effects on bedrock and related resources for transportation facilities under Alternative 3B would be the same as those described for Alternative 2, except that there would be no indirect effects on bedrock from expansion of the Dutch Harbor fuel storage facility. There would be no difference in direct effects on bedrock along the mine access road, material sites, or airstrip.

## Diesel Pipeline

Effects on bedrock and related resources under Alternative 3B would be the same as Alternative 2, except for some off-ROW facilities located in shallow bedrock areas. These include new airstrips required to support potential oil spill recovery (OSR) activities, airstrips that remain open during the operations phase, and required helipads at valve locations. There is no shallow bedrock along the pipeline ROW between Beluga and Tyonek that would be affected by the added pipeline segment in this area. Of 3 additional new airstrips required under this alternative, one (George River) would require some cut and fill construction and is located in an area of shallow bedrock. This airstrip would potentially affect an additional 60 acres of bedrock. Other new airstrips and helipads would either require grading only (low intensity impacts) or are not located in shallow bedrock areas.

The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would still be considered local (within the footprints of various facilities). The additional area of shallow bedrock potentially affected under Alternative 3B is small compared to the total estimated under Alternative 2 for the pipeline (e.g., about 500 acres off-ROW, and about 70 miles or up to 2,600 acres of ROW).

### 3.1.3.4.2 SURFICIAL GEOLOGY

## Mine Site

With the exception of reduced fuel storage capacity at the mine site, effects on surficial deposits and gravel resources under Alternative 3B are generally the same as those described for Alternative 2. The decreased fuel storage capacity required at the mine under this alternative would reduce the required fuel storage footprint by roughly 75 percent in comparison to Alternative 2 (from 15 tanks down to 4), resulting in roughly 10 acres less fuel storage under Alternative 3B at the mine site, although the same area may be disturbed for other purposes (e.g., laydown). The reduction in fuel storage footprint under this alternative is small compared to overall areas of effects on surficial deposits for the mine site as a whole (roughly 9,000 acres).

## Transportation Facilities

The area of effects on surficial deposits at the Angyaruaq (Jungjuk) Port would likely be similar under this alternative to that of Alternative 2, as fuel storage capacity would be needed at this site for the construction period. Thus, the site footprint would be similar to that of Alternative 2. There would be less indirect effect on surficial deposits at the Bethel and Dutch Harbor ports due to less amount of fuel storage required. The reduction in effects would be the same as described under Alternative 3A (Section 3.1.3.3.2).

## Diesel Pipeline

Effects on surficial deposits and aggregate resources would increase as a result of Alternative 3B due to additional trenching and material sites (up to 5) between Beluga and Tyonek, and additional cut and fill construction and/or grading for new airstrips and helipads. Cut-and-fill construction along the Tyonek-Beluga segment of the ROW would be minimal due to low relief topography in this area. The areas of potential cut and fill under this alternative include those described for Alternative 2 (totaling about 11,600 acres, about 1,100 more than Alternative 2), plus roughly an additional 5 acres for trenching, 60 acres for additional material sites, and 200 acres for new airstrips.

The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would still be considered local (within the footprints of various facilities). Since the additional areas of surficial deposits potentially affected under Alternative 3B are small compared to the total estimated under Alternative 2 for the pipeline.

### 3.1.3.4.3 PALEONTOLOGICAL RESOURCES

#### Mine Site

Effects on paleontological resources at the mine site under Alternative 3B would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for this project component.

#### Transportation Facilities

Effects on paleontological resources resulting from the construction, operations, and closure of transportation facilities under Alternative 3B would be similar to Alternative 2. The reduced levels of barge traffic and low water travel on the Kuskokwim River corridor would cause less potential effects on Quaternary fossils in riverbank deposits near relay points. Effects under this alternative would be the same as described under Alternative 3A (Section 3.1.3.3.3).

#### Diesel Pipeline

Effects on paleontological resources under Alternative 3B would be similar to Alternative 2, except that the increase in shallow bedrock cuts at one new airstrip, and increase in cuts in surficial deposits at 5 pipeline material sites, could potentially cause a slight increase in the probability of encountering either dinosaur track fossils in Kuskokwim Group rocks or Pleistocene vertebrates in surficial deposits. As described above under Bedrock and Surficial Geology, the additional areas of bedrock and surficial deposits potentially affected by the pipeline under Alternative 3B are small compared to the totals estimated under Alternative 2.

### 3.1.3.4.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 3B

Direct effects on bedrock, mineral/rock aggregate resources, surficial deposits, and paleontological resources at the mine site under Alternative 3B would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock or paleontological resources, or the amount of mineral resource reduction or aggregate use. There would be decreased fuel storage capacity at the mine site under this alternative, which reduces the fuel storage footprint. However, the reduction is small when compared to the overall areas of effects on surficial deposits for the mine site as a whole, and does not change the overall impact ratings. Like Alternative 2, overall impacts from the mine site under Alternative 3B are considered minor to moderate.

For the transportation facilities, effects on bedrock and related resources under Alternative 3B would be similar to those described for Alternative 2. There would be no difference in direct effects on bedrock along the mine access road, material sites, or airstrip. The small reductions in impacts from Alternative 2 associated with Alternative 3B transportation facilities would be the same as described under Alternative 3A. Overall impacts associated with transportation facilities under Alternative 3B are considered minor to moderate.

While some increased impacts to geologic resources would occur under Alternative 3B at off-ROW diesel pipeline facilities, the increase would be relatively small compared to the rest of the pipeline component for resources that are considered mostly common in context. The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would still be considered local (within the footprints of various facilities). The additional areas of bedrock and surficial deposits potentially affected under Alternative 3B are small compared to the total estimated under Alternative 2 for the natural gas pipeline. Therefore, the minor to moderate overall level of effects associated with the diesel pipeline under Alternative 3B would be considered the same as Alternative 2.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required for Alternative 3B, the summary impact rating would remain similar to Alternative 2; minor to moderate.

### 3.1.3.5 ALTERNATIVE 4 – BIRCH TREE CROSSING (BTC) PORT

#### 3.1.3.5.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the mine site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for the mine site.

Transportation Facilities

Effects on bedrock and rock aggregate resources would increase under Alternative 4 due to additional bedrock material sites required for construction, and the fact that BTC Road would traverse about 10 more miles of shallow bedrock than the mine access road in Alternative 2. The BTC Road would utilize sedimentary and volcanic rock aggregate sourced from 37 material sites (Section 3.1.2.2.3 – Affected Environment), which is more than 3 times the number under Alternative 2 (there are 12 bedrock material sites along the mine access road in Alternative 2). Bedrock material sites under Alternative 4 would cover about 1,160 acres, or about 5 times more area than that under Alternative 2 (240 acres). Likewise, the total volume of rock aggregate that would potentially be utilized from bedrock material sites under Alternative 4 is roughly 13.8 million cy, or about 5 times that of the Alternative 2 mine access road (2.8 million cy). The large increase in rock aggregate for the BTC Road is partly due to the increased road length (43 miles longer than Alternative 2) and partly due to more gravel aggregate availability under Alternative 2 (discussed below under Section 3.1.3.5.2, Surficial Geology). As the types of construction activities would be the same under Alternative 4 as for Alternative 2, the range of intensity of effects on bedrock resources would be the same, although more blasting would be required under Alternative 4.

Natural Gas Pipeline

Effects on bedrock and related resources associated with the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for the pipeline and associated facilities.

#### 3.1.3.5.2 SURFICIAL GEOLOGY

Mine Site

Effects on surficial geology and gravel resources at the mine site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

Transportation Facilities

Effects on surficial deposits under Alternative 4 would be similar to Alternative 2, except that the additional 43 miles of the BTC Road would require roughly 35 percent more cut and fill along slide slopes with cuts into overburden. While the BTC Road would utilize gravel aggregate sourced from 5 material sites compared to only 1 for the mine access road under Alternative 2 (Section 3.1.3.2.2), the 5 BTC material sites combined would yield slightly less extraction volume and cover less acreage than the one under Alternative 2. The total volume and area of gravel material sites under Alternative 4 would be about 0.9 million cy and cover 170 acres, compared to 1.1 million cy covering 240 acres for Alternative 2. Because the types of construction activities would be the same under Alternative 4 as for Alternative 2, the range of intensity of effects on surficial geologic resources would be the same as Alternative 2.

Natural Gas Pipeline

Impacts to surficial geology and gravel resources associated with the construction, operations, and closure of the natural gas pipeline under Alternative 4 would be the same as discussed under Alternative 2.

#### 3.1.3.5.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources at the mine site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for this project component.

Transportation Facilities

Potential effects on pre-Quaternary paleontological resources would be higher under Alternative 4 than Alternative 2. As described above under Section 3.1.3.5.1, Alternative 4 – Bedrock, approximately five times as much bedrock would be utilized for rock aggregate for the BTC Road than for the mine access road. Of the total number of bedrock material sites along the BTC Road, 25 contain Kuskokwim Group sedimentary rock with the potential for dinosaur fossils (as compared to 3 sedimentary rock material sites along the mine access road). Although known fossil assemblages and outcrops are sparse in the western portion of the route, the potential for encountering dinosaur fossils in these rocks is considered similar to that of the mine and northern part of the mine access road corridor under Alternative 2 (Section 3.1.3.2.3 – Paleontological Resources), and could range from low to high intensity (minor grading to blasting). The remaining bedrock material sites and the BTC Port are located in areas of non-fossiliferous igneous, volcanic, and metamorphic rocks.

Potential effects on Quaternary vertebrate fossils along the Kuskokwim River corridor would be reduced under Alternative 4. The reduction on upper river barge travel under this alternative would eliminate travel through several critical sections upstream of the BTC Port (e.g., Aniak, Holokuk, Upper Oskawalik), where barges would need to be relayed during low water periods under Alternative 2. Thus, the Pleistocene vertebrate fossils identified in this area under Alternative 2 would be avoided.

Natural Gas Pipeline

Impacts to paleontological resources associated with the natural gas pipeline under Alternative 4 would be the same as discussed under Alternative 2.

#### 3.1.3.5.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 4

For the mine site and the natural gas pipeline components, direct effects on bedrock, mineral / rock aggregate resources and paleontological resources under Alternative 4 would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock or surficial deposits, or the amount of mineral resource reduction or gravel aggregate use for the mine site under this alternative. Overall impacts associated with the mine site and the natural gas pipeline under Alternative 4 are considered minor to moderate.

The geographic extent and volume of bedrock usage for the transportation facilities would be larger under Alternative 4 than under Alternative 2. The large increase in rock aggregate for the BTC Road is partly due to the increased road length (43 miles longer than Alternative 2) and partly due to less gravel aggregate availability under Alternative 4. The total volume and area of gravel material sites under Alternative 4 would be about 0.9 million cy and cover 170 acres, compared to 1.1 million cy covering 240 acres for Alternative 2. The increased number of bedrock material sites along the BTC Road would increase the probability of potential effects on bedrock paleontological resources under Alternative 4, but effects on Quaternary vertebrate fossils in surficial deposits along the Kuskokwim River would be less under Alternative 4. Because the types of construction activities would be the same under Alternative 4 as for Alternative 2, the intensity of effects on bedrock and rock aggregate resources, and surficial geologic resources would be the same as Alternative 2, ranging from low (e.g., minor scraping) to high (e.g., blasting, permanent reduction of material resources, landform scars). As with Alternative 2, potential beneficial effects from exposure of new fossils in material site outcrops would be dependent on adoption of additional mitigation measures (see Chapter 5, Impact Avoidance, Minimization, and Mitigation). The extent of impacts would be considered local as they would be limited to areas within the various facility footprints, and the context of impacts would be common to important. Overall impacts associated with transportation facilities under Alterative 4 would be considered minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required for Alternative 4, the summary impact rating would remain similar to Alternative 2; minor to moderate.

### 3.1.3.6 ALTERNATIVE 5A – DRY STACK TAILINGS

#### 3.1.3.6.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and aggregate resources at the mine site under Alternative 5A would be similar to those described for Alternative 2. There would be minor differences in the amount of bedrock and rock aggregate resources disturbed and distributed during Alternative 5A. Waste rock that would be used for capping of the TSF under Alternative 2 would be used to cap the upstream dry stack tailings instead, as the main dam and impoundment under Alternative 5A would be removed at closure. Waste rock that would be used for the reclaim causeway at the TSF under Alternative 2 would be placed in the WRF under Alternative 5A. An increased amount of rock fill sourced mostly from the open pit would be used to construct both the main dam and dry stack tailings dam under Alternative 5A. There would be an increased amount of shallow bedrock excavated at the TSF under this alternative for foundation preparation for both dams. Filling of the upper Anaconda Creek valley with the dry stack tailings would result in similar landform and topographic changes as Alternative 2, in that the final dry stack tailings elevation would be roughly 400 feet higher than the original valley bottom, although the final elevation of the dry stack would be 150 feet higher than the top of the TSF under Alternative 2. The top of the dry stack would rise 50 to 150 feet above the ridge on its south side, whereas the TSF under Alternative 2 would not rise above the surrounding landscape.

While there would be minor differences in the amount of bedrock excavated and rock fill used between Alternatives 2 and 5A, the types of construction effects, mineral and aggregate resource reductions, and range of the magnitude of effects would be the same as Alternative 2. Like Alternative 2, impacts to bedrock under Alternative 5A would be local, i.e., within the footprint of the mine facilities.

Transportation Facilities

Effects on bedrock and related resources along the transportation corridor under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for transportation facilities.

Natural Gas Pipeline

The effects to bedrock from natural gas pipeline construction, operations, and closure under Alternative 5A would be the same as Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for this project component.

#### 3.1.3.6.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

Mine Site

Effects on surficial deposits and gravel resources at the mine site under Alternative 5A would be similar to those described for Alternative 2. There would be minor differences in the area and volume of surficial deposits disturbed and distributed under Alternative 5A. There would be about a 12 percent increase in the amount of excavation and storage required for construction of both the main dam and upper dry stack tailings dam (BGC 2014a), as well as an increase in the amount of gravel resources required for use as filter material in the two dams.

While there would be a minor increase in the amount of surficial deposits disturbed and gravel resources needed under Alternative 5A as compared to Alternative 2, the types of construction effects, overall magnitude of resource reductions, and range of the intensity of effects would be the same as Alternative 2. Like Alternative 2, impacts under Alternative 5A would be local, i.e., within the footprint of the mine facilities.

Transportation Facilities

Effects on surficial geology and gravel resources along the transportation corridor and associated facilities under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

Natural Gas Pipeline

Surficial geology and gravel aggregate impacts experienced as a result of Alternative 5A would be the same as discussed under Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

#### 3.1.3.6.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources under Alternative 5A would be similar to Alternative 2, except for an additional area of potentially fossil-bearing bedrock beneath the dry stack tailings and holding pond that would be covered during operations and inaccessible for future research, and additional volumes of shallow weathered bedrock excavated for dam foundations. The areas of bedrock coverage during the closure period would be roughly the same between Alternatives 2 and 5A.

#### Transportation Facilities

Effects on paleontological resources along the transportation corridor and at associated facilities under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components.

#### Natural Gas Pipeline

Paleontological resource impacts associated with the natural gas pipeline under Alternative 5A would be the same as discussed under Alternative 2.

### 3.1.3.6.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 5A

While there would be small differences in the amount of bedrock excavated and rock fill used between Alternatives 2 and 5A at the mine site, the types of construction effects, mineral and aggregate resource reductions, and range of the magnitude of effects would be the same as Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would also be minor differences in the area and volume of surficial deposits disturbed and distributed under Alternative 5A, but these differences would not change the criteria ratings from Alternative 2 associated with the mine site. Impacts would range from low intensity (e.g., areas of minor grading of bedrock during closure) to high intensity (e.g., blasting and resource removal, major landform changes, and widespread aggregate resource utilization). These activities would result in the permanent alteration of resources in a localized area. Effects on paleontological resources at the mine site under Alternative 5A would be similar to Alternative 2, except for an additional area of potentially fossil-bearing bedrock beneath the dry stack tailings and holding pond that would be covered during operations and inaccessible for future research, and additional volumes of shallow weathered bedrock excavated for dam foundations. The overall impacts to geologic resources at the mine site would be minor to moderate.

Effects on bedrock, mineral / rock aggregate resources, surficial deposits, gravel resources, and paleontological resources under along the transportation corridor and the natural gas pipeline under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance associated with these facilities. Overall impacts at the transportation facilities and natural gas pipeline under Alternative 5A would be minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required for Alternative 5A, the summary impact rating would remain similar to Alternative 2; minor to moderate.

### 3.1.3.7 ALTERNATIVE 6A – MODIFIED NATURAL GAS PIPELINE ALIGNMENT: DALZELL GORGE ROUTE

#### 3.1.3.7.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the mine site under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use between the two alternatives.

Transportation Facilities

Effects to bedrock and related resources from transportation facilities construction, operations, and closure would be the same as discussed under Alternative 2.

Natural Gas Pipeline

Effects on bedrock and aggregate resources along the pipeline under Alternative 6A would be similar as those described for Alternative 2, with minor differences. Alternative 6A traverses steeper terrain requiring additional cut and fill, which could potentially expose more bedrock and require additional aggregate resources. There is almost no shallow bedrock within trenching depth along either of the Alaska Range segments of these alternatives. The number of bedrock material sites in the Alaska Range sections of Alternatives 6A and 2 are roughly the same. Under Alternative 6A, one material site (Airfield Quarry) located near MP 108.5 would utilize sedimentary bedrock and impact an area approximately 22 acres in size. Similarly, there is only one bedrock material site along the Alaska Range section of Alternative 2, which encompasses about 29 acres together with co-located gravel resources.

#### 3.1.3.7.2 SURFICIAL GEOLOGY

Mine Site

Effects on surficial geology and gravel resources at the mine site under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use.

Transportation Facilities

Surficial geology and gravel resources impacts associated with the transportation facilities under Alternative 4 would be the same as described under Alternative 2.

Natural Gas Pipeline

The types of effects on surficial deposits and gravel resources along the pipeline corridor under Alternative 6A would be similar to Alternative 2 with minor differences. Ten material sites that would utilize stream channel alluvial gravel deposits have been identified for the Alternate 6A route within the Alaska Range from roughly MP 114.5 to MP 150.5, as compared to 13 gravel material sites for the Alaska Range portion of Alternative 2. Collectively, the 10 material sites under Alternative 6A cover a smaller area than those of Alternative 2, with a total potential utilization area of approximately 110 acres (compared to 230 acres for the Alternative 2 sites). The largest utilization of alluvial gravel under Alternative 6A would occur from Dalzell Creek at MP 123.6 that would impact approximately 29 acres.

The total lengths of ROW that would impact surficial deposits under Alternatives 2 and 6A are comparable, as there is only about a 1- to 2-mile difference in length for the two routes. While the Dalzell Gorge route would traverse a greater length of steep unstable slopes along the ROW (see Section 3.3, Geohazards and Seismic Conditions), the total length of gentler cross-slopes (with greater than 6 percent grade) that would require cut and fill construction and a wider construction ROW is less under Alternative 6A than Alternative 2. The Alaska Range segment of Alternative 2 would require roughly 98 percent (or 46 miles) of cut and fill construction, whereas the Dalzell Gorge segment of Alternative 6A would require about 85 percent (or 38 miles) of cut and fill construction.

#### 3.1.3.7.3 PALEONTOLOGICAL RESOURCES

Mine Site and Transportation Facilities

Effects on paleontological resources at the mine site and transportation facilities under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components.

Natural Gas Pipeline

As presented in Section 3.1.2.3.4 and shown on Figure 3.1-5, the Alaska Range segments of the pipeline routes under Alternatives 2 and 6A pass through the McGrath and Tyonek quadrangles with similar paleontological occurrences along both routes. Thus, impacts to paleontological resources under Alternative 6A are expected to be generally similar to Alternative 2.

#### 3.1.3.7.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 6A

Effects on bedrock, mineral / rock aggregate resources, surficial deposits, gravel resources, and paleontological resources at the mine site and transportation facilities under Alternative 6A would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components. Overall impacts would be minor to moderate.

Under Alternative 6A, effects on geologic resources along the pipeline would be similar as those described for Alternative 2, with minor differences. There would be a small variation in the amounts of bedrock and rock aggregate utilized along the pipeline as compared to Alternative 2. The number of bedrock material sites in the Alaska Range sections of Alternatives 6A and 2 are roughly the same. The total lengths of ROW that would impact surficial deposits under Alternatives 2 and 6A are also comparable, as there is only about a 1- to 2-mile difference in length for the two routes. Collectively, the 10 material sites under Alternative 6A cover a smaller area than those of Alternative 2, with a total potential utilization area of approximately

110 acres (compared to 230 acres for the Alternative 2 sites). The Alaska Range segments of the pipeline routes under Alternatives 2 and 6A pass through the McGrath and Tyonek quadrangles with similar paleontological occurrences along both routes. Thus, impacts to paleontological resources under Alternative 6A are expected to be generally similar to Alternative 2. These minor differences between alternatives would not change the range of overall impacts of minor to moderate for geologic resources. Impacts to geologic resources along the pipeline would range from low intensity (e.g., areas of minor grading) to high intensity (e.g., blasting and resource removal, major landform changes, and widespread aggregate resource utilization). These activities would result in the permanent alteration of resources in a localized area. Overall impacts associated with the pipeline under Alternative 6A would be minor to moderate.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2. If additional mitigation and monitoring measures described for Alternative 2 were adopted and required for Alternative 6A, the summary impact rating would remain similar to Alternative 2; minor to moderate.

### 3.1.3.8 IMPACT COMPARISON – ALL ALTERNATIVES

Although there are differences among alternatives in the project components that would affect geology, they are relatively small. This is because all alternatives involve excavation and removal of large amounts of surface and bedrock materials, with such removals being necessary for construction and operations of the mine site, transportation facilities, pipeline, and supporting facilities. The scope and scale of the project are such that minor changes to routing and alignments result in little change to overall impacts. Most of the alternatives being considered have relatively minor impacts on Project Area or construction needs. A summary for the impacts from the alternatives is presented in Table 3.1-5 below.

### Table 3.1-5: Comparison of Impacts by Alternative*

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| **Mine Site** | | | | | | |
| Bedrock Geology | Permanent alteration of about 505 Mt of ore and 2,765 Mt of waste rock from the 1,462 acre pit, and final elevation changes up to about 600 feet. | Same as Alt. 2 | Same as Alt. 2 | Same as Alt. 2 | Final elevation of dry stack 50-150 feet higher than south ridge. | Same as Alt. 2 |
| Surface Geology | Permanent change to roughly 40 Mt of overburden covering about 9,000 acres. | Same as Alt. 2 | 10 acres < Alt. 2 | Same as Alt. 2 | Aggregate needed for dams about 12 % > Alt. 2 | Same as Alt. 2 |
| Paleontology | Permanent alteration of potential fossil-bearing rock over 1,492-acre pit. | Same as Alt. 2 | Same as Alt. 2 | Same as Alt. 2 | Minor additional impact | Same as Alt. 2 |
| Summary Impact Level | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate |
| **Transportation Facilities** | | | | | | |
| Bedrock Geology | 16 miles of road; an additional 400 acres at other facilities (airstrip, camp, material sites); and reduction of about 2.8 Mcy of bedrock aggregate resources. | 5 acres < Alt. 2 | 5 acres < Alt. 2 | 960 acres 11.2 Mcy<br>> Alt. 2 | Same as Alt. 2 | Same as Alt. 2 |
| Surface Geology | Ground disturbance and landform alterations across a total of about 700 acres and reduction of about 1.5 Mcy of gravel resources. | 10 to 20 acres < Alt. 2 | 5 acres < Alt. 2 | 70 acres, 0.2 Mcy < Alt. 2 | Same as Alt. 2 | Same as Alt. 2 |

**Table 3.1-5: Comparison of Impacts by Alternative***

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| Paleontology | Potential localized impacts in areas having fossil potential: road cuts along 7 miles of northern part of mine/airstrip access roads, airstrip, 3 material sites, and 2 low-water relay points. | Reduced impacts along Kuskokwim | Same as Alt. 3A | Greater impact to bedrock fossils along the BTC Road, and less impact to vertebrate fossils along the Kuskokwim River. | Same as Alt. 2 | Same as Alt. 2 |
| Summary Impact Level | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate |
| **Pipeline** | | | | | | |
| Bedrock Geology | 70 miles of ROW and associated infrastructure bedrock material sites covering a total of 500 acres; and a total reduction of about 2.8 Mcy of bedrock aggregate resources. | Same as Alt. 2 | 60 acres > Alt 2 | Same as Alt. 2 | Same as Alt. 2 | 7 acres less |
| Surface Geology | 262 miles of ROW and 80 miles of shoofly roads where cross-slopes may require cut and fill construction; roughly 2,100 acres of associated infrastructure; and would result in a total reduction of about 3.1 Mcy of gravel resources. | Same as Alt. 2 | 1,365 acres > Alt. 2 | Same as Alt. 2 | Same as Alt. 2 | 3 less material sites<br>120 acres less than Alt. 2 |

**Table 3.1-5: Comparison of Impacts by Alternative***

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| Paleontology | Potential localized impacts within project footprint at locations having fossil potential: pre-Quaternary and Quaternary deposits along roughly 262 miles of ROW, 80 miles of shoofly roads, and material sites covering about 1,000 acres. | Same as Alt. 2 | Minor additional impacts | Same as Alt. 2 | Same as Alt. 2 | Same as Alt. 2 |
| Summary Impact Level | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate |

**Notes:**

* The No Action Alternative would have no new impacts.

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